DOCUMENT RESUME

ED 129 605 SE 021 400

AUTHOR Angelo, Joseph A., Jr.
TITLE Stamps Tell the Story of Nuclear Energy.
INSTITUTION Energy Research and Development Administration, Oak Ridge, Tenn.
PUB DATE 75
NOTE 96p.; Photographs of stamps may not reproduce well

EDRS PRICE MF-$0.83 HC-$4.67 Plus Postage.
DESCRIPTORS Elementary Secondary Education; *Nuclear Physics; *Physics; *Science History; *Scientists
IDENTIFIERS *Energy Research and Development Administration; ERDA; Postage Stamps

ABSTRACT

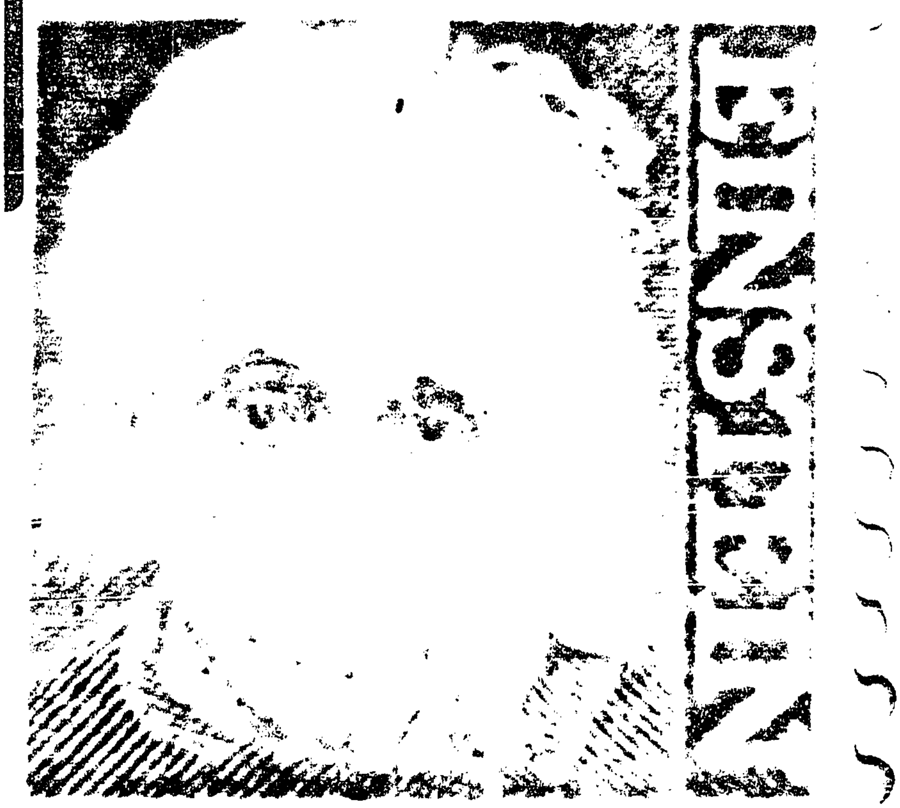
This document provides a summary history of the individual scientists principally responsible for the development of nuclear physics and a survey of modern utilization of atomic energy. Identified throughout the booklet are postage stamps illustrating each individual and topic discussed. (SL)

# Stamps Tell the Story of Nuclear Energy

by Joseph A. Angelo, Jr.







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Oak Ridge, Tennessee 37830

Captain Joseph A. Angelo, Jr. received his Ph.D and M.S. degrees from the University of Arizona. He was an astronautical engineer and nuclear research officer in the U. S. Air Force Space & Missile Systems Organization in California. He is now a staff research physicist at Patrick Air Force Base in Florida and is an adjunct faculty member of the Florida Institute of Technology. He has presented scientific papers in the fields of radioactive waste management and nuclear engineering education at professional conferences, which include the 1973 American Nuclear Society Winter Meeting in San Francisco, the March 1973 International Atomic Energy Agency Symposium in Paris, France, and the "Waste Management 1974" Meeting in Tucson, Arizona.

U. S. Energy Research and Development Administration
Office of Public Affairs
Washington, D. C. 20545

Library of Congress Catalog Card Number: 73-600332
1975

# Introduction

## ABOUT THIS BOOKLET

Unlocking the secrets of the atom was the lifework of many great men in the past. Ensuring the continued productive application of atomic energy also requires the work of many dedicated persons now and in the future. For atomic energy, properly utilized, holds out the promise of abundant power—the key to economic progress—as well as the promise of more food, better health, and greater productivity—the keys to social progress.

Many nations throughout the world, including the United States, have honored the atom, its applications, and its famous scientists with special postage stamps. This collection of "atomic postage stamps" was prepared to help tell the story of the atom—a story that includes its discovery, current applications, and future potential.

Although every effort has been made to include as wide and interesting a collection of postage stamps as possible, this collection cannot be considered complete since new stamps are being issued almost daily throughout the world. But that is precisely the pleasure associated with philately, which is the hobby of collecting postage stamps. It, like the story of the atom itself, is a dynamic, constantly growing and developing process.

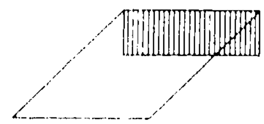
Therefore, whether you are a scientist or layman, stamp collector or noncollector, it is hoped that this short comprehensive visit to the world of the atom through the use of selected atomic postage stamps will be both enjoyable and informative. If you want to learn more about nuclear energy, you might wish to consult the books on page 75.

Stamps used as illustrations in this booklet are marked with a number and asterisk in the list beginning on page 78; the number is the page on which the stamp appears.

## How To Mount A Stamp

Collectors usually mount stamps in albums with stamp hinges or special mounts available from stamp dealers and some stationery stores.

The hinge is usually flat and gummed on one side. It is prepared for use by (1) folding it about one-third of its length with the gummed side out. (2) The short end is then moistened slightly and applied to the stamp so that the folded edge is just below the perforations at the top. (3) Next, the long end is lightly moistened and the stamp is placed in its proper position over the lines in the album. Hinges of this type are peelable when dry. Therefore, if you need to reposition the stamp in your album, be sure to wait until the gum on the hinge has become thoroughly dry; otherwise, either the page or the stamp may be damaged.



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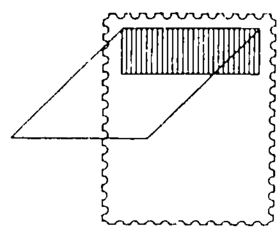

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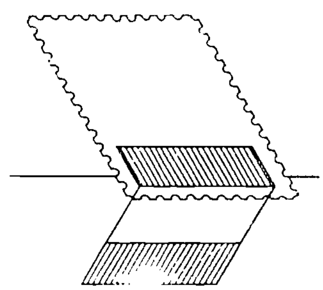


3

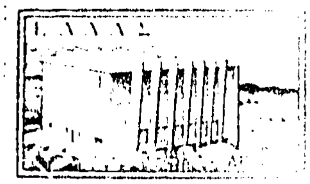
## ABOUT STAMP COLLECTING

The noncollector who wants to begin the hobby of stamp collecting should read one or more of the stamp collecting guidebooks, which are listed on page 76. These books provide an excellent in-depth introduction to the entire field of philately.

Second, if possible, visit a stamp dealer in your area. He is usually a dedicated professional who will not only supply you with the stamps and accessories necessary to start your hobby, but will also provide much valuable advice on the development of your collection and the care of your stamps.

Spaces for stamps have been provided throughout the text. In addition, several blank pages in the back of the booklet may be used to mount and display other atomic postage stamps. A WORD OF WARNING! Do NOT secure your stamps in this booklet or any other place with paste, glue, transparent tape, metal staples, or by moistening the glue on unused stamps. Any of these actions will permanently affix these stamps and possibly destroy any value they might have. Stamps should be mounted and secured with either stamp hinges or other special mounts provided by stamp dealers.

For the stamp collector who wishes to build an atomic stamp collection, a listing of most of the world's atomic stamps is in the appendix beginning on page 78.



Country: Greece. Year: 1961. Colors: rose lilac and deep lilac rose. Denomination: 2.5 drachma. Subject: The Democritus Nuclear Research Center. A companion stamp is on page 8.


Country: Turkey. Year: 1963. Denomination: 50 kurush. Colors: red brown, and black. Subject: The design features an atomic symbol superimposed on a map of Turkey. Part of a set that commemorated the first anniversary of the Turkish Nuclear Research Center. A companion stamp is on page 39.

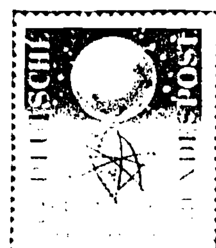
Country: Czechoslovakia. Year: 1963. Colors: gray brown and light green. Denomination: 1.60 koruna. Subject: A nuclear rocket approaching the planet Jupiter. Part of a set honoring space flight. Issued as a companion to next stamp.


Country: Czechoslovakia. Year: 1963. Colors: yellow and dark purple. Denomination: 2 koruna. Subject: A nuclear rocket approaching the planet Saturn.

# Discovering the Atom

The story of nuclear energy centers around the curiosity of people about the very nature and structure of matter. Especially in the last few decades, man has made great progress in unlocking the secrets of the atom. Although the complete story involves the work of thousands of persons, only a few of the more famous atomic scientists, who have been honored by special postage stamps, will be discussed in this booklet. For additional information about the lives and contributions of these scientists as well as the many others who have contributed to atomic research but are not mentioned here, see the reading list at the end of the booklet and *Atomic Pioneers: Books 1-3*, *The First Reactor*, *A Bibliography of Basic Books on Atomic Energy*, and *Worlds Within Wo[illegible] The Story of Nuclear Energy*, other booklets in this series

*Country: Federal Republic of (West) Germany. Year: 1955. Denomination: 20 pfennig. Color: rose brown. Subject: Nuclear research.*




THE GREEKS HAD A WORD FOR IT

As far as we can tell, the theory of "atomism"—that is, that all matter consists of minute, indivisible particles—originated with the ancient Greeks. The Greek School of Atomism is believed to have been founded at Abdera in the 5th century B.C. by Leucippus.

However, the work of Leucippus was overshadowed by that of his brilliant student Democritus.

Democritus was born around 460 B.C. in Abdera, Thrace, and died about 380 B.C., place unknown. He was perhaps the greatest of the Greek atomistic philosophers and is often called "the father of ancient atomic theory". For Democritus the universe consisted of only two basic things: The fullness of matter and the vacuum of empty space. All matter was actually composed of tiny particles, called atoms, which were considered to be eternal, unchanging, indestructible, and indivisible. Like all of his contemporaries, Democritus based his ideas strictly on deductive reasoning without recourse to experimentation. His views of the universe, crude of course by modern standards, were nonetheless far closer to present concepts than those of most of the other Greek philosophers, including Socrates, Plato, and Aristotle.


*Country: Greece. Year: 1961. Denomination: 4.50 drachma. Colors: pale violet blue and violet blue. Subject: Democritus.*

## A WORLD OF AIR, EARTH, FIRE, AND WATER

Although the idea that matter is composed of atoms originated with the ancient Greeks some 2500 years ago, it was not until the scientific revolution, which began in the 16th and 17th centuries, that man began to

examine his world experimentally and renew his interest in atomic theory. At the birth of modern science, the concept of the atom, as an elementary part of matter, was revived by such great scientists as Galileo Galilei, Isaac Newton, and Robert Boyle, from the extremely thin and tenuous path it had followed through the intervening centuries from ancient Greece.

Up until that time scientists were apparently content with the Aristotelian interpretation of the "four-element universe", which stated that all matter was composed of air, earth, fire, and water. However, even to such great thinkers as Galileo, Newton, and Boyle, the atom remained a rather vague and general concept. It was left to John Dalton, an early 19th-century English chemist, to begin the experiments by which the atom became a concrete, identifiable, and universally accepted scientific entity.

## THE PERIODIC TABLE

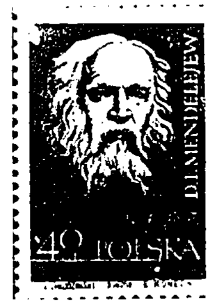
John Dalton and others in the early part of the 19th century developed the concept that all matter consisted of a relatively small number of chemical elements, each of which was made up of tiny, identical, indivisible atoms. Molecules were considered to be atoms combined in definite proportions. However, by the mid-19th century the field of chemistry was in a state of chaos and confusion, due to a general lack of agreement on how to determine the atomic weights of different elements.

In 1858 the Italian scientist Stanislao Cannizzaro recognized and brought attention to the significance of the work of another Italian scientist, Amedeo Avogadro. More than 40 years earlier in 1811 Avogadro had formulated two key hypotheses concerning the nature of molecules: (1) All gases under the same conditions of temperature and pressure contain the same number of molecules, and (2) A molecule may consist of more than one atom. This work proved to be a catalyst that inspired the Russian chemist Dmitri Mendeleev to successfully devise the Periodic Table of the Elements, which established a plausible relationship between the elements in each group and their chemical and physical properties.

Dmitri Mendeleev was born in Tobol'sk, Siberia, in 1834 and died in St. Petersburg (now called Leningrad) in 1907. In 1869 he published his Periodic Table of the Elements, which was arranged by atomic weight. He continued to improve this table and in 1871 published a revised version in which he left gaps for elements not yet discovered but whose existence he then boldly predicted. Within 15 years three of these elements—gallium, germanium, and scandium—all having properties predicted by Mendeleev were actually discovered.

Mendeleev's Periodic Table helped to organize the chaotic concepts of the chemical elements. Through his work the idea of atomic chemistry, originally proposed by John Dalton, was eventually expanded into a complete theory of the nature of matter by

*Country: Poland. Year: 1959. Color: olive gray. Denomination: 40 groszy. Subject: Dmitri Mendeleev.*



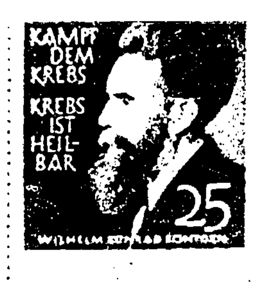

the end of the 19th century. In his honor the synthetic transuranic element with atomic number 101 was called mendelevium (symbol Md) in 1955.

## X RAYS ARE DISCOVERED

The German physicist, Wilhelm Konrad Roentgen, was born in Lennep, Prussia, in 1845 and died in Munich, Germany, in 1923. During the initial part of his professional career he was a professor of physics at several German universities. In 1885 he became the director of the Physical Institute at the University of Würzburg, and it was here that Roentgen discovered X rays.

This discovery occurred in the fall of 1895, while Roentgen was investigating the luminescence that cathode rays produced in certain chemicals. Luminescence may be de-

*Country: Danzig. (Danzig was established as a Free City State in 1920, seized by Germany in 1939, and became a Polish Province in 1945.) Year: 1939. Denomination: 25 pfennig. Color: dark olive green. Subject: Wilhelm Roentgen.*



fined as the emission of light produced by the action of chemical or biological processes, by radiation, or by other causes except high temperature (which produces incandescence). Roentgen darkened the laboratory in order to better observe the luminescence phenomenon and saw that a distant sheet of paper, coated with barium platinocyanide, was glowing.

This sheet continued to remain luminescent, despite the fact that the cathode-ray tube itself was covered with heavy black paper during its operation. When the tube was shut off, the sheet of barium platinocyanide no longer glowed; but when the current of the cathode-ray tube was restored, the coated paper again glowed. Roentgen concluded that some type of mysterious, invisible radiation, which had great penetrating power and was different from cathode rays, was being emitted from the cathode-ray tube.

Using the conventional mathematical symbol X for an unknown quantity, he called these mysterious rays X rays. In fact, X rays are a penetrating form of electromagnetic radiation, which are emitted either when the inner orbital electrons of an excited atom return to their normal state (these are called characteristic X rays) or when a metal target is bombarded with high-speed electrons (these are called bremsstrahlung).

For his discovery of X rays Wilhelm Roentgen was awarded the first Nobel Prize in physics in 1901. This discovery was not only a great aid to the practice of medicine, but also led to new insights into the structure of the atom. For example, within months after

*Country: France Year: 1946. Denomination: 2 + 3 francs. Color: violet. Subject: Fiftieth anniversary of the discovery of radioactivity by Henri Becquerel.*

Roentgen's discovery, the phenomenon of radioactivity was discovered by the French physicist Antoine Henri Becquerel.

## THE DISCOVERY OF RADIOACTIVITY

The French physicist Antoine Henri Becquerel was born in Paris in 1852 and died at Croisic in Brittany in 1908. For his discovery of radioactivity he shared the 1903 Nobel Prize in physics with Pierre and Marie Curie.

Several months after Roentgen's discovery of X rays, Becquerel began to study fluorescent materials, such as potassium uranyl sulfate (a uranium salt), to see if penetrating rays like Roentgen's X rays were emitted from them. Many substances can absorb energy in the form of X rays, radioactive particles, or ultraviolet light, and then immediately emit this energy as an electromagnetic photon (often called a photon of visible light). This emission is called fluorescence and the emitting substances are said to be fluorescent.

In February 1896 Becquerel placed a thin crystal of the uranium salt on a photographic plate, which had been wrapped in black paper, and then exposed this package to sun-

light. Several days of cloudy weather prevented him from continuing his sunlight-exposure experiments and he put the apparatus away for a few days. When he returned to the laboratory, he developed the wrapped photographic plate, which had been stored near some uranium salt but didn't expect to find anything. To his surprise the photographic plate showed a degree of darkening far greater than previously achieved in his earlier experiments.

Although neither Becquerel nor anyone else at that time understood the process of radioactive decay, he concluded that the radiations given off by the uranium salt did not depend on sunlight and were not associated with fluorescence. Subsequent investigation showed him that these mysterious rays penetrated matter and were emitted continuously by the uranium salt. These new radiations were called "Becquerel rays" until about 1898, when the emission of this type of radiation was called radioactivity by Pierre and Marie Curie.

Radioactivity is the process whereby an unstable atomic nucleus spontaneously decays or disintegrates. This decay is usually accompanied by the emission from the nucleus of three common types of radiation called alpha particles, beta particles, and gamma rays.

The alpha particle (symbol $\alpha$) is a positively charged particle made up of two protons and two neutrons bound together and is therefore identical with the nucleus of a helium atom. It is the least penetrating of these three types of radiation.

The beta particle (symbol $\beta$) is another elementary particle that can be emitted from the nucleus during radioactive decay. A negatively charged beta particle is identical to the electron; while a positively charged beta particle is called a positron. Although more penetrating than alpha particles, beta particles are stopped by a thin sheet of metal.

The gamma ray (symbol $\gamma$) is high-energy, short-wavelength electromagnetic radiation. Gamma rays are essentially similar to X rays. However, they are usually more energetic than X rays and are nuclear in origin. Gamma rays are very penetrating and are stopped by dense materials such as lead.

## RADIUM AND POLONIUM

The French physicist, Pierre Curie, was born in 1859 and met an untimely death at the age of 47 in a Parisian street accident in 1906. As part of his doctoral degree studies, Pierre Curie investigated the magnetic properties of metals. One of his outstanding contributions to the field of physics was his discovery that the magnetic properties of certain

*Country: Sweden. Year: 1963. Denomination: 50 ore. Color: chocolate. Subject: The three winners—Henri Becquerel, Pierre Curie, and Marie Curie—of the 1903 Nobel Prize in Physics.*


*Country: France. Year: 1967. Colors: dark blue and ultramarine. Denomination: 60 centimes. Subject: Centenary of the birth of Marie Curie. The design includes a glowing bowl of radium.*

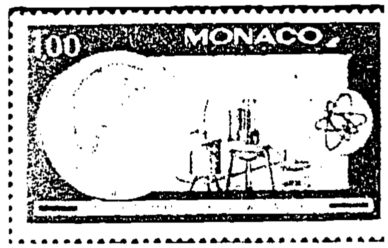
materials change at a critical temperature, which was later called the Curie point. Above the Curie point, ferromagnetism suddenly disappears or is greatly reduced.

Despite his earlier scientific achievements, Pierre Curie became known predominantly for his work on radioactivity, which he carried out jointly with his wife the French-Polish chemist, Marie Sklodowska Curie. She was born in Warsaw in 1867 and died in Haute Savoie, France, in 1934. While studying in Paris in 1894 she met Pierre Curie and they were married a year later. They had two daughters, Eve and Irène. Irène Joliot-Curie and her husband Frederic Joliot were also scientists and received the Nobel Prize in chemistry in 1935.

Roentgen's discovery of X rays in 1895 and Becquerel's discovery of the radioactive

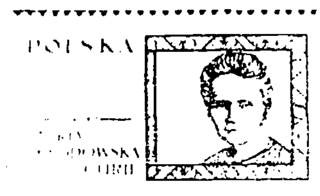

*Country: Central African Republic. Year: 1968. Colors: brown, bright blue, and violet. Denomination: 100 francs. Subject: Marie Curie. In the design is the zodiacal symbol of cancer (representing the disease) being destroyed by an arrow (representing radiation).*

*Country:* Monaco *Year:* 1967. *Colors:* olive, ultramarine, and brown. *Denomination:* 1 franc. *Subject:* The centenary of the birth of Marie Curie.




properties of uranium in 1896 so intrigued Marie Curie that she immediately began studying the radioactivity of uranium. Later her husband, Pierre, joined in these experiments and together they carried on a systematic investigation of the radioactive properties of the mineral pitchblende, a uranium ore.

*Country:* Poland. *Year:* 1963. *Denomination:* 60 groszy. *Color:* blue. *Subject:* Marie Curie.




They performed these experiments in a wretched little shed that the School of Physics had given them. It was suffocatingly hot in summer, brutally cold in winter, and the roof leaked. Their precision instruments were often affected by the humidity and the temperature changes.

*Country:* France. *Year:* 1938. *Denomination:* 1.75 + 0.50 francs. *Color:* deep ultramarine. *Subject:* Fortieth anniversary of the discovery of radium by Pierre and Marie Curie.

Marie Curie has said of this time ". . . And yet it was in this miserable old shed that the best and happiest years of our life were spent, entirely consecrated to work. I sometimes passed the whole day stirring a mass in ebullition, with an iron rod nearly as big as myself. In the evening I was broken with fatigue." "In our poor shed there reigned a great tranquillity: sometimes, as we watched over some operation, we would walk up and down, talking about work in the present and in the future; when we were cold a cup of hot tea taken near the stove comforted us. We lived in our single preoccupation as if in a dream."

In 1898 they announced the discovery of two new radioactive elements, which they had extracted after years of grueling experiments in their shed. From the pitchblende these new elements were called polonium, in honor of Marie Curie's native country of Poland, and radium.

Pierre and Marie Curie jointly shared with Becquerel the 1903 Nobel Prize in physics for the discovery of radioactivity. When her husband was tragically killed in 1906, she succeeded him as professor of physics at the Sorbonne, a university in Paris, and became the first woman ever to teach there. In 1911 she was awarded a second Nobel Prize (this time in chemistry) for her work on radium and its chemical compounds.

In honor of the Curies the synthetic transuranic element with atomic number 96 was named curium (symbol Cm). In addition, the basic unit describing the radioactive intensity in a sample of material is called the curie.

One curie (symbol c) is equal to 37 billion disintegrations per second, which is approximately the rate of radioactive decay of one gram of radium.

## QUANTUM THEORY

The German physicist, Max Planck, the formulator of the quantum theory, was born in Kiel, Schleswig, in 1858 and died in Göttingen, Germany, in 1947.

At the time, there was a tendency among scientists to believe that the laws of physics had all been discovered. This attitude is well illustrated by the following advice that Max Planck received when he was 17 years old from a physics professor: "Physics is a branch of knowledge that is just about complete. The important discoveries, all of them, have been made. It is hardly worth entering physics anymore."

*Country: West Germany (Berlin). Year: 1953. Denomination: 30 pfennig. Color: brown violet. Subject: Max Planck.*


A major problem that baffled physicists in the late 19th century was the evaluation of the spectral distribution of the thermal radiation emitted by a black body. Thermal radiation is the energy transferred by electromagnetic waves, which originate from a body by virtue of its temperature. This thermal radiation is usually associated with molecular rota-

tion and/or molecular vibration. A black body is a perfect absorber and a perfect radiator of thermal radiation.

At the turn of the century excellent experimental thermal radiation data could not be reconciled with the various theoretical radiation energy distribution equations that had been developed. Some of these theoretical models were valid at long wavelengths, while other theoretical models were valid only at short wavelengths. Then in 1900 Max Planck proposed an equation that accurately described the distribution of thermal radiation over the entire range of wavelengths (both long and short). However, Planck's thermal radiation distribution function required that radiant energy be absorbed or emitted by the perfect (black body) system only in separate energy packets, which he called *quanta* (from the Latin word *quantus*, meaning "how much"). This model seemed very strange at the time and many scientists were slow to realize fully its significance.

Max Planck's application of his quantum theory concept to the problem of thermal radiation from a black body proved to be a satisfactory theoretical interpretation of the experimentally observed phenomena. The energy (E), associated with each quantum, is given by the equation:

$$E = h\nu$$

where E = the energy of the quantum or of a photon (which is the carrier of a quantum of electromagnetic radiation).

$\nu$ = the frequency of the radiation.
h = Planck's constant (a fundamental constant of the universe).

Because of the revolutionary impact that Planck's quantum theory had on the field of physics, its significance was not really firmly established until after Einstein successfully applied quantum theory to the problem of photoelectric emission and Niels Bohr used quantum theory to develop his theory of atomic structure and spectra. By 1918, however, the value of the quantum theory had become apparent to all and Max Planck was awarded the Nobel Prize in physics that year.

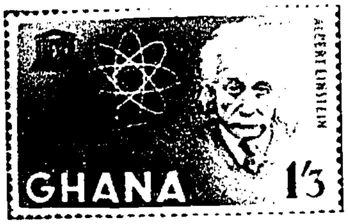
## MASS AND ENERGY ARE EQUIVALENT

Albert Einstein, the great German-American physicist, was born in Ulm, Germany, in 1879 and died in Princeton, New Jersey, in 1955.

As a child he was a slow learner, and at one point he dropped out of school. Before he left, one of his teachers said, "You will never amount to anything, Einstein."

In 1901 the father of a friend got him a job in the patent office in Bern, Switzerland. This position left him ample time to develop some of the most profound concepts in theoretical physics, which he published in 1905 when he was 26 years old. Each of these works contained a great discovery in theoretical physics. These were: (1) the creation of the Special Theory of Relativity, which included the establishment of the mass-energy

equivalence; (2) the development (based on Planck's Quantum Theory) of the photoelectric effect and of the photon theory of light; and (3) the theory of Brownian motion,




*Country: Ghana. Year: 1964. Colors: claret and Prussian blue. Denomination: 1 shilling, 3 pence. Subject: Albert Einstein.*

which concerns the irregular motion of microscopic particles suspended in a gas or liquid.

In 1909 he was professor of theoretical physics at the University of Zurich, and in 1914 he became professor at the University of Berlin and director of the Kaiser Wilhelm Physics Institute.

In 1916 Einstein greatly expanded his Special Theory of Relativity when he published his General Theory of Relativity, which contained a radically new concept of gravitation. He was awarded the Nobel Prize in physics in 1921 for his development of the photo-


*Country: Poland. Year: 1959. Color: claret. Denomination: 60 groszy. Subject: Albert Einstein.*

electric law and for his work in theoretical physics.

Increasingly apprehensive over the rise of Hitler in Germany, Einstein was visiting the United States in 1933 when the Nazis confiscated his property and took away his job and citizenship. He had already been offered the

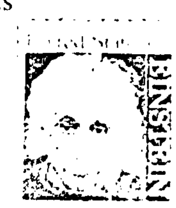
directorship of the school of mathematics in the newly created Institute of Advanced Study in Princeton, New Jersey. He accepted the position and remained there until his death.

*Country: Israel. Year: 1956. Color: brown Denomination: 350 prutot. Subject: Albert Einstein.*


Einstein was a humanist as well as a physicist. He devoted many days to helping individuals and mankind in general.

When he died, Einstein left physics a vastly changed science as a result of his own contributions. His Theory of Relativity, which constitutes one of the great theoretical foundations of 20th-century physics, has had profound effects in mechanics and electromagnetism, and has led to new insights into the nature of time and space. Perhaps one of the most important consequences of Einstein's work in the field of nuclear science is

*Country: The United States. Year: 1966. Color: violet. Denomination: 8 cents. Subject: Albert Einstein.*



the principle of the equivalence of mass and energy:

$$E = mc^2$$

where E = energy
m = mass
$c^2$ = speed of light squared

This mass-energy equivalence helps to explain the vast amounts of energy produced when the atomic nucleus is split in nuclear fission or when atomic nuclei combine in nuclear fusion.

In his honor a synthetic transuranic element of atomic number 99 was named einsteinium (symbol Es).

## THE ATOMIC NUCLEUS

The brilliant British physicist, Ernest Rutherford, has often been called the "father of nuclear science". The identification of alpha particles, the modern theory of radioactivity, the concept of the atomic nucleus, and the achievement of the first man-made nuclear reaction are among his outstanding contributions to nuclear science.

Ernest Rutherford was born in 1871 near Nelson, New Zealand, and died in 1937 in Cambridge, England. After graduating from Canterbury College in New Zealand, he won a scholarship at Trinity College, Cambridge University, where he worked for several years under the British physicist J. J. Thomson.

In 1898 Rutherford accepted a position as professor of physics at McGill University in


*Country: Canada. Year: 1971. Colors: red, orange, and black. Denomination: 6 cents. Subject: The centenary of the birth of Ernest Rutherford.*

*Country: New Zealand. Year: 1971. Colors: gray, silver, and multicolored. Denomination: 1 cent. Subject: Ernest Rutherford. His gold foil experiment, upon which he based his theory of the atomic nucleus, is in the design.*


Montreal, Canada. It was here that he began his great contributions to nuclear science. At McGill University Rutherford worked for nearly a decade studying radioactivity. Together with the British chemist, Frederick Soddy, he published a series of papers that helped create the modern theory of radioactivity. Rutherford first carefully determined the difference between alpha and beta radiation and then used these distinctions to study the process of radioactive decay.

In the course of his investigations of radioactivity he also demonstrated that alpha particles were really helium "atoms" (later realized to be the nuclei of helium atoms). The nucleus is the small, positively charged core of an atom. It is only about $\frac{1}{10,000}$ the diameter of the atom but contains nearly all the atom's mass. All nuclei contain both protons and neutrons, except the nucleus of ordinary hydrogen, which consists of a single proton. The term nuclide is a general expression that pertains to all the isotopic forms of all the elements. Nuclides are distinguished by their atomic number, atomic mass, and energy state.

Rutherford returned to England in 1907 to accept a professorship in physics at Manchester University. In 1908 he was awarded the Nobel Prize in chemistry for "his investigations of the chemistry of radioactive substances". Following his return to England, he established a center for the study of radioactivity at Manchester.

One of his experiments had a most profound effect on the theory of atomic structure. In this experiment a stream of alpha particles was directed at a thin piece of gold foil. Some of the alpha particles were deflected at very sharp angles. "It was quite the most incredible event that ever happened to me in my life. It was almost as incredible as if you fired a 15-inch shell at a piece of paper and it came back and hit you". Based on this experiment Rutherford proposed the nuclear concept in which each atom has all of its positive charge and virtually all of its mass concentrated in a tiny space at its center.

In 1914 Rutherford was knighted. After World War I he achieved the first man-made nuclear reaction, when he bombarded nitrogen atoms with alpha particles and produced protons. This reaction, which involved the first artificial transmutation of one element into another, was:

$$^{4}_{2}He + ^{14}_{7}N \rightarrow ^{17}_{8}O + ^{1}_{1}H$$

where $^{4}_{2}He$ = the alpha particles (helium atom nuclei), which were used as "nuclear bullets".

$^{14}_{7}N$ = the nitrogen nuclei, which were the "nuclear targets".

$^{17}_{8}O$ = the nuclei of the oxygen isotope produced in the experiment.

$^{1}_{1}H$ = the proton (hydrogen atom nucleus), which was also produced in the reaction.

Rutherford was a marvelous teacher and infected his students with his own enthusiasm for scientific research. Among his many illustrious students were Hans Geiger, Ernest Walton, Otto Hahn, Frederick Soddy, James Chadwick, etc. His students said of him, "He had none of the meaner faults and was just as willing to attend to the youngest student and if possible learn from him as. . .to listen to any recognized scientific authority. He made us feel as if we were living very near the center of the scientific universe."

He had a short temper, which he sometimes displayed when experiments were not going to his satisfaction. When things ran smoothly, he would walk through the laboratory singing "Onward Christian Soldiers".

Rutherford was president of the Royal Society from 1925 until 1930 and was made First Baron Rutherford of Nelson in 1931.

## THE BOHR ATOM

The Danish physicist, Niels Bohr, was born in Copenhagen, Denmark, in 1885 and died there in 1962. His quantum theory of atomic structure, which is called the Bohr atom, is often considered a cornerstone of modern atomic physics.

One of Bohr's old schoolmates was asked. "What characteristic of Niels Bohr do you rate the highest?" He answered, "His goodness. . .Let us not give examples. Bohr would not care for that. You must be satisfied with my word when I tell you that he is as good in big things as in small. I am not exaggerating when I say that I consider him the best human being in the world."

In 1911 the University of Copenhagen awarded Bohr his doctorate. Upon graduation he left Denmark to join the British scientist,

*Country: Denmark. Year: 1963. Color: dark blue. Denomination: 60 ore. **Subject:** Niels Bohr. In the design are an electron in orbit around a nucleus and Bohr's electron orbital energy equation. Part of a set honoring Niels Bohr on the 50th anniversary of his formulation of the "Bohr Atom" model.*

Sir J. J. Thomson, at the Cavendish Laboratory in Cambridge, England. Bohr, always modest and unassuming, wrote to his fiancée about his first meeting with Thomson: "He was extremely kind. I believe he thought there was some sense in what I said. . .", Bohr then journeyed to Manchester in 1912 to work with Ernest Rutherford, who said of him, "This young Dane is the most intelligent chap I've ever met." It was through this association that Niels Bohr considered combining the Rutherford model of the atomic nucleus

and Max Planck's quantum theory to create a quantum theory of atomic structure, which would satisfy the experimental data relating to atomic structure, particularly the hydrogen atom spectrum. The hydrogen atom spectrum (or actually the spectrum of any chemical element in monatomic gaseous form) is composed of a group of sharp, discrete lines. Each spectrum is characteristic of the particular chemical element. For example, the hydrogen atom, excited by high temperatures or electric discharge, emits a characteristic set of frequencies, called the emission spectrum. When a continuous frequency band of electromag-

*Country: Greenland. Year: 1963. Color: red brown. Denomination: 35 ore. Subject: (Same description as previous stamp.)*

netic radiation is sent through the hydrogen gas, this same set of frequencies is also absorbed.

Niels Bohr was able to explain the experimentally observed spectrum of hydrogen by developing the Rutherford nuclear atom model with the following modifications: (1) the electron makes a circular orbit around the nucleus; (2) only certain discrete (quantized) electron orbits are allowed; and (3) an electron going from a high energy orbit ($E_2$) to a lower energy orbit ($E_1$) gives up energy in the form of a photon according to the conservation of energy principle. From these assumptions Bohr developed his formula:

$$h\nu = E_2 - E_1$$

where $\nu$ = the frequency of the electromagnetic radiation associated with the photon.

$E_1$ = the electron energy in lower energy orbit.

$E_2$ = the electron energy in higher energy orbit.

h = Planck's constant.

With this radical atomic model Bohr was able to calculate the frequencies of the entire spectrum of the hydrogen atom. The basic assumptions of the Bohr atom model are still fundamental considerations in present-day theories of atomic structure.

Niels Bohr was appointed director of the Institute for Theoretical Physics at the University of Copenhagen in 1920. Two years later he received the Nobel Prize in physics for his work on atomic structure as developed in the Bohr atom model. He also developed the basic ideas for the "liquid drop model of the nucleus"—a model that makes the fissioning of a heavy nucleus analogous to the rupturing of a liquid drop. In 1943 he fled his native land of Denmark, which was then under Nazi occupation, and escaped to the United States, where he worked as an advisor to the Manhattan Project (the secret project that developed the world's first atomic bomb for the United States). After World War II he returned to the Institute of Theoretical Physics in Copenhagen.

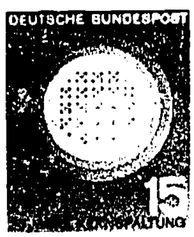
J. Robert Oppenheimer summed up Bohr's contribution in this way: "Our under-

standing of atomic physics, of what we call the quantum theory of atomic systems, had its origins at the turn of the century and its great synthesis and resolutions in the nineteen-twenties. It was a heroic time. It was not the doing of any one man; it involved the collaboration of scores of scientists from many different lands, though from first to last the deeply creative and subtle critical spirit of Niels Bohr guided, restrained, deepened, and finally transmuted the enterprise. It was a period of patient work in the laboratory, of crucial experiments and daring action, of many false starts and many untenable conjectures. It was a time of earnest correspondence and hurried conjectures, of debate, criticism, and brilliant mathematical improvisation. For those who participated, it was a time of creation; there was terror as well as exaltation in their new insight. It will probably not be recorded very completely as history. As history, its re-creation would call for an art as high as the story of Oedipus or the story of Cromwell, yet in a realm of action so remote from our common experience that it is unlikely to be known to any poet or historian."

## THE NUCLEAR AGE IS BORN

Otto Hahn was born in Frankfurt-am-Main, Germany, in 1879 and died in Göttingen, West Germany, in 1968. For his work on uranium fission he received the Nobel Prize in chemistry in 1944.

Hahn received his Ph. D. from the University of Marburg in 1901. He began to study radioactive materials with William Ramsay at the University of London and continued at McGill University in Montreal under Ernest Rutherford. He returned to Germany in 1912 to work at the Kaiser Wilhelm Institute. He became its director and much of his work on the atom was done there. In 1918 together with Lise Meitner he discovered the new element protactinium. They continued to collaborate during the next 15 years.




*Country: Federal Republic of Germany (West). Year: 1964. Colors: ultramarine, black, and bright green. Denomination: 15 pfennig. Subject: Twenty-fifth anniversary of the discovery of uranium fission by the German scientists, Otto Hahn and Fritz Strassmann. The stamp shows the core of a nuclear reactor, including the characteristic blue glow of Čerenkov radiation.*

In the 1930s Hahn and Meitner became intrigued with experiments performed by the Italian physicist Enrico Fermi. Fermi had bombarded uranium with neutrons and the products from this experiment led him, and others, to believe that artificial elements had been formed.

Meitner and Hahn began experiments in this area in 1938, but, before they could finish she was forced to flee Germany because

of the Nazi persecution of Jews. Hahn and another researcher, Fritz Strassmann, continued this work.

In the fall of 1938 Hahn and Strassmann bombarded uranium with neutrons from a radium-beryllium source. To their surprise the element barium was found in the residue from the experiment. The differences between the atomic masses of barium and uranium caused a great deal of excitement in the laboratory. They wondered where the barium came from! Hahn speculated that the radioactive barium which had been discovered might have been produced as a result of the splitting of the uranium atom itself. (This process would later be called nuclear fission.) However, the concept of splitting a nucleus was so novel to Hahn that he hesitated to give it a detailed theoretical interpretation.

Hahn and Strassmann told Lise Meitner of their observations and also that they were hesitant to publish their findings. Together with her nephew, Otto Frisch, who was working with Niels Bohr, she immediately gave a theoretical interpretation to the experiment and published a paper to this effect in January 1939.

This paper described the fission of a heavy nucleus into two unstable fission fragments, which would then undergo radioactive decay. This fission process was also accompanied by the release of a large amount of energy, representing some of the mass of the uranium nucleus that had "disappeared" in the fission reaction. Using Einstein's mass-energy equivalence formula:

this expected energy release was calculated by Meitner and Frisch to be about 200,000,000 electron volts per uranium nucleus fissioned. (The electron volt is the amount of kinetic energy gained by an electron when it is accelerated through an electric potential difference of 1 volt.)

Frisch told Bohr about this exciting news just as he (Bohr) was leaving for a meeting in Washington, D. C. Bohr discussed it with Fermi, who met him at the New York harbor, and also announced it at the meeting. It created a sensation and the scientists rushed home to confirm it with experiments of their own! In these conversations with Bohr, Fermi suggested the possibility that neutrons might be released in the fission process and the concept of the neutron chain reaction began to form in their minds.

Enrico Fermi was born in Rome in 1901 and died in Chicago in 1954. In 1922 he graduated from the University of Pisa. In 1934 Fermi began to bombard uranium with neutrons and thereby created many artificial radioactive isotopes. It was not until several years later that anyone, even Fermi himself, realized that the process of nuclear fission had actually occurred in some of these early experiments. For his work on artificial radioactive substances Fermi was awarded the Nobel Prize in chemistry in 1938. He cleverly used the trip to Sweden to receive this award as a way to escape with his family from Fascist Italy. He then came to the United States and taught at Columbia University.

*Country: Italy. Year: 1967. Colors: orange brown, and black. Denomination: 50 lire. Subject: Twenty-fifth anniversary of the world's first self-sustained nuclear chain reaction. The Italian-American physicist, Enrico Fermi, and the world's first nuclear reactor are in the design.*


Bohr, Fermi, and many other scientists who had fled the Nazis were afraid that Germany would pursue nuclear fission research and possibly develop a super weapon. They knew that a number of German scientists were studying nuclear fission, and that the Nazis had attempted to speed up the production of heavy water in a Norwegian plant. They believed that this heavy water was being accumulated as a moderator for a plutonium-producing nuclear pile. A letter to President Roosevelt stating this situation was drafted and Einstein, as the most prominent scientist in the country, was asked to sign it.

Because of this, the Manhattan Project was organized. The purpose of this top secret program was to try to beat the Germans in the race to develop the new weapon using nuclear fission.

As part of that effort, Enrico Fermi headed a team of scientists at the University of Chicago that was attempting to create man's first controlled, self-sustaining neutron chain reaction. A chain reaction is a reaction

that stimulates its own repetition. In a fission chain reaction, a fissionable nucleus absorbs a neutron and splits or fissions, subsequently releasing additional neutrons. These neutrons in turn can be absorbed by other fissionable nuclei, releasing still more neutrons. The chain reaction is called self-sustaining when the number of neutrons released in a given time equals or exceeds the number of neutrons lost by absorption and leakage.

At 3:36 p.m. (Chicago time) on December 2, 1942, the Nuclear Age was born! Fermi's group achieved the world's first self-sustained neutron chain reaction and Chicago Pile One (CP-1), as Fermi's experimental assembly of uranium and graphite blocks was called, became the world's first nuclear reactor. Arthur Compton, one of the scientists at Chicago, immediately telephoned a colleague, James B. Conant, at Harvard. Their code was not prearranged.

"The Italian navigator has landed in the New World," said Compton.

"How were the natives?" asked Conant.

"Very friendly."

After World War II Fermi returned to teach at the University of Chicago. Two days before he died in 1954 he received an award (subsequently named after him) from the U. S. Atomic Energy Commission for his outstanding achievements in the field of nuclear energy. In his honor the transuranic element of atomic number 100 was called Fermium (symbol Fm).

# Using Atomic Energy

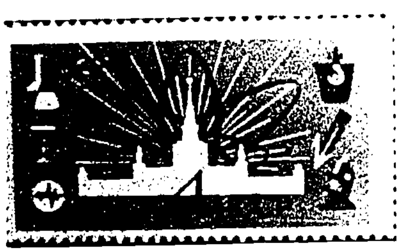
This portion of the booklet covers radioisotopes, nuclear explosives, nuclear reactors, and atomic energy organizations. While you explore the dynamic world of atomic philately you will also discover the fascinating world of the atom and the potential it offers. For additional information on the material covered in this section, see the books in the reference list and *Radioisotopes in Medicine*, *Radioisotopes in Industry*, *Nuclear Power Plants*, *Atoms in Agriculture*, *Preserving Food with Atomic Energy*, *Atomic Energy and Your World*, *Power from Radioisotopes*, and *Worlds Within Worlds: The Story of Nuclear Energy*, other booklets in this series.

## RADIOISOTOPES

The existence of the radioisotope was discovered about 1913, after more than 10 years of experimentation with naturally radioactive materials. When two or more atoms with the same atomic number have different atomic weights, they are called isotopes. The atomic number is the number of protons in the nucleus of an atom and also its positive charge. The atomic weight of an atom is its mass in relation to other atoms. The atomic mass number is the sum of the number of neutrons and protons in a nucleus and is the nearest whole number to the atomic weight.

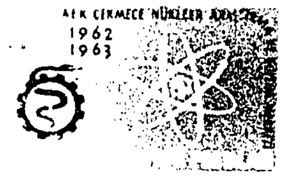
For example, $^{233}_{92}U$, $^{235}_{92}U$, $^{238}_{92}U$, and $^{239}_{92}U$ are all isotopes of the chemical element uranium (symbol U). The subscript (92) is the common atomic number, while the superscripts (233, 235, 238, and 239) are different mass numbers (the approximate atomic weights of these uranium isotopes). A radioisotope is an unstable isotope of an element that disintegrates or decays spontaneously while emitting radiation. More than 1400 natural and artificial radioisotopes have been discovered and identified.

Radioisotopes have unstable nuclei and undergo spontaneous disintegration (decay). They differ from each other in the rate at which they decay and in the type of radiations they emit when they decay. This rate of decay is usually measured in terms of the time required for half the unstable nuclei to disintegrate. This characteristic time is called the radioisotope's half-life. Half-lives can be as short as millionths of a second and as long as billions of years. For example, $^{228}_{92}U$ has a half-life of 9.3 minutes; $^{231}_{92}U$ a half-life of



*Country: Russia (USSR). Year: 1962. Colors: orange, brown, yellow, and black. Denomination: 4 kopecks. Subject: Applications of radioisotopes in medicine, research, agriculture, and industry. This stamp features an atom superimposed on an outline of the Kremlin. On either side are symbols of the various fields in which radioisotopes are used. Part of a set honoring the concept of "Atoms for Peace".*

*Country: Turkey. Year: 1963. Colors: green, dark green, red, and yellow. Denomination: 60 kurush. Subject: Part of a set commemorating the first anniversary of the Turkish Nuclear Research Center near Istanbul. In the design are symbols of agriculture, medicine, and industry.*




4.2 days; $^{232}_{92}U$ a half-life of 72 years; and $^{235}_{92}U$ a half-life of some 713,000,000 years. All these radioisotopes belong to the same chemical element, uranium (mass number 92). The variation in stability of the radioisotopes results from a difference in the number of neutrons in the nucleus, as indicated by the different atomic masses; for example, in the case of uranium, the atomic masses are 228, 231, 232, and 235.

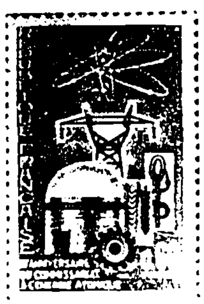
We use the characteristic decay of radioisotopes in several different ways. Whenever a radioisotope decays, measurable amounts of radiation—alpha particles, beta particles, or gamma rays—are emitted. This radiation can be traced easily with radiation detection equipment. Investigation of the movement of a radioisotope that is chemically identical to the material under study also reveals the movement of its nonradioactive isotope.

As radiation passes through matter it loses energy until it is eventually stopped or weakened. How far a particular type of radiation penetrates depends on the thickness, density, and atomic number of the absorbing material as well as on the energy of the radiation itself.

As radiation passes through matter it loses intensity and the energy associated with this energy loss appears as the energy of the excited electrons of the absorbing material's atoms and as heat. Thus the thickness and in some cases the composition of a substance may be determined by measuring the radiations that pass through that substance.

## RADIOISOTOPES IN INDUSTRY

Radioisotopes are used in industry primarily in processing, measuring, and testing. An unusual property, which makes them useful in many industrial applications, is that they are detectable in extremely small quantities. For example, it is possible to detect as



*Country: France. Year: 1965. Colors: bright blue and black. Denomination: 60 centimes. Subject: Twentieth anniversary of the French Atomic Energy Commission. The design is a composite showing a nuclear reactor surrounded by the symbols of industry, agriculture, and medicine.*

little as $4 \times 10^{-17}$ ounce of radioactive iron-59. This isotope is used frequently as a tracer in mechanical wear-test programs. Isotopes with short half-lives are the most desirable tracers for short experiments because radioactivity soon decays to negligible quantities after the isotope has done its job. On the other hand, when radioisotopes are used in long experiments, for example, as heat

sources, power sources, in radiography, or in chemical analysis, long-lived radioisotopes (that is, those with long half-lives) are desirable so that frequent and costly replacements of the isotope are avoided.

While there are some naturally occurring radioisotopes, such as potassium-40, which make up a small portion of all potassium, most industrially used radioisotopes are produced in nuclear reactors or with particle accelerators. Although nearly 1500 different radioisotopes have been discovered and identified, only about 100 of these are produced regularly for specific applications. Most of the remainder have half-lives that are far too short to be useful in commercial or industrial applications.

*Country:* *Canada.* *Year:* *1966.* *Color:* *deep ultramarine.* *Denomination:* *5 cents.* *Subject:* *The peaceful uses of nuclear energy. The design contains a drawing of the Douglas Point Nuclear Power Station, Lake Huron, Ontario; a microscope; a dove (symbol of peace); and an atomic symbol.*


Radioisotope thickness gauges have been developed that detect, record, and even make possible automatic control of the thickness of a manufactured product. The gauge consists of a radioisotope source (for example, cobalt-60 or cesium-137), a radiation detector, and an indicator. The material passes between the radiation source and the radiation detector, and the amount of radiation measured by the

detector and recorded by the indicator is proportional to the thickness and the density of the material. Using this technique, the thickness of something like paper can be controlled within fine tolerances even under high-speed production.

Radiography is the process of taking pictures with radiation other than visible light. For example, a dental X ray is a radiograph. Usually radiographs are made with X or gamma rays. These "pictures" are not photographs in the ordinary sense but are shadowgraphs. A shadowgraph results when an object stops part of the X or gamma rays. The variation in intensity of the emerging radiation is, of course, proportional to the thickness, density, and atomic number of the intervening object. That is, where the object is thin, less dense, or of lower atomic number, more radiation passes through, and this can activate that part of the radiation absorbent material in an X-ray film pack. The opposite is true for areas where the object is thick, dense, or has a higher atomic number. Thus a detailed picture of an object's interior can be made without opening it.

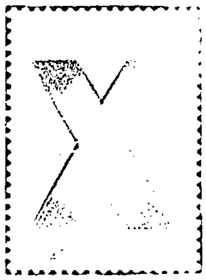
X rays are frequently produced by bombarding solid, heavy-metal targets (such as copper, tungsten, or tantalum) with high-speed electrons. These electrons are then deflected by the heavy nucleus and emit high-frequency electromagnetic radiation, which is called X ray, or bremsstrahlung (a German word that means "braking radiation"). X rays are not nuclear in their origin, although they may be produced as a by-product of nuclear events.

On the other hand, gamma rays occur when unstable nuclei undergo radioactive decay and some of the reaction energy appears as very high-frequency electromagnetic radiation. Radioisotopes, like cobalt-60 and cesium-137, provide an economical and portable source of gamma radiation with which to perform such industrial activities as radiographic inspections. These inspections are used in a wide variety of commercial situations, such as hull inspecting in the shipbuilding industry, ensuring vacuum seal integrity in the canning business, and checking welds in the construction trade.

## RADIOISOTOPES IN MEDICINE

Radioisotope use in medicine began in 1901 with radium. As a matter of fact, until about 1946, radium was the most important medical radioisotope. In that year artificially produced radioisotopes became abundant, and since then the use of radioisotopes in medicine has grown very rapidly. Their unique attributes have become more apparent to greater numbers of physicians and scientists for medical research, therapy, and diagnosis. Over a dozen different radioisotopes in various forms are used in medical procedures today.

The field of biomedical research that uses radioisotopes as tools is so large that detailed coverage is required to do it justice. Thus, the use of radioisotopes in medicine for diagnosis and for therapy will be discussed only briefly here.



*Country: Japan. Year: 1966. Colors: multicolored. Denomination: 15 + 5 yen. Subject: Medical X rays.*

In medical diagnosis radioisotopes are used as tracers. In this role, small, essentially harmless quantities of the radioactive tracer atom aid the diagnostician in obtaining information about normal and abnormal life processes. A radioactive tracer corresponds in chemical nature and behavior to the element it traces. For example, a molecule of hemoglobin, containing some radioactive iron-59 atoms, is still hemoglobin and it is treated by the body just as if it were nonradioactive (or "untagged") hemoglobin. However, with some radioactive iron-59 atoms in the hemoglobin molecule, the diagnostician can, with proper radiation detection equipment, follow these molecules wherever they go in the body. And thus he can study the general flow characteristics of the hemoglobin and observe normal and abnormal bodily processes.

In therapy, radioisotopes are used primarily as radiation sources. In this application the choice of the radioactive isotope is


*Country: Japan. Year: 1966. Colors: orange, black, and yellow. Denomination: 7 + 3 yen. Subject: The role of radioisotopes in radiation therapy. A modern cobalt-60 treatment facility is in the design. Part of a set commemorating the Ninth International Anticancer congress held in Tokyo.*

*Country: Norway. Year: 1931. Color: carmine. Denomination: 20 + 10 ore. Subject: Norwegian Radium Hospital.*

governed largely by the type and energy of the emitted radiation and by its range (distance traveled) in the body tissues or organs being subjected to the radiation therapy. In radiotherapy, a radioactive material emits radiations that can destroy existing cells and prevent the formation of new ones in an organ or tissue of the body. Thus, this therapy is used when a diseased tissue or organ is causing physiological harm to the rest of the body through overactivity or when extensive cellular metabolic malfunctions are occurring.

The use of cobalt-60 to destroy malignant tumors is one of the most well-known forms of radiotherapy. Another example of radiotherapy is the use of iodine-131 to treat cases of hyperthyroidism (that is, an overactive thyroid gland). In this case therapeutic doses* of $^{131}I$ accumulate in the diseased thyroid

*A therapeutic dose uses much higher concentrations of the radioisotope than are used in diagnostic tests.

*Country: The Republic of Niger. Year: 1966. Colors: brown, violet, deep claret, and blue green. Denomination: 100 francs. Subject: Ninth International Anticancer Congress held in Tokyo. In the design atomic radiation symbolically destroys the zodiacal symbol of cancer (representing the disease).*

gland, irradiate the thyroid cells from within the gland, damage and destroy the thyroid tissue, and thereby reduce the activity of the overactive thyroid. This procedure is, of course, a far more desirable mode of radiotherapy than bombarding the diseased thyroid with an external radiation source (such as cobalt-60), since there is less danger of radiation damage to the surrounding healthy tissues.

## RADIOISOTOPES IN AGRICULTURE

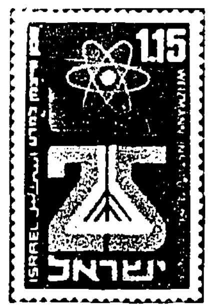
In an effort to reduce crop losses due to weeds, insects, and disease and to raise the standard of living, agricultural research has become a complex science, which includes the use of radiation sources and radioisotopes as tracers. Nuclear techniques are used to study soils, plants, microbes, insects, farm animals, and the preservation of foodstuffs. Radioactive atoms are used in agricultural research conducted by various government and private groups throughout the world; from such research efforts come improved agricultural techniques, materials, and products that are then used by the farmers.

In agricultural research, scientists study plant nutrition and metabolism using radioactive tracers. Photosynthesis is the process whereby green plants use energy from the sun to convert simple compounds from air (carbon dioxide) and soil (water and minerals) into complex, energy-rich substances; it has been called the most important chemical reaction in the world. It is the basis for man's

entire food and much of his fiber supply and, except for nuclear energy and hydroelectric power, all significant fuel as well. Radioisotope tracer techniques have greatly expanded and accelerated the research efforts on photosynthesis. In addition, radioactive tracers have also been used to study plant diseases and weeds, animal nutrition and metabolism, and insecticides.

Radioisotopes are also used in agriculture as radiation sources. In the past, one very interesting question arose: Can radiation produce new plants? After more than three decades of scientific study, certain conclusions have emerged concerning this intriguing question. High-energy radiations can cause hereditary changes (mutations) in any living thing: Mammal, insect, microbe, and plant. Any feature of a plant subject to hereditary control, such as root, shoot, leaf, flower, or fruit, can be altered by radiation.

*Country: Israel. Year: 1969. Colors: violet blue and multicolored. Denomination: 1.15 Israeli pounds. Subject: Twenty-fifth anniversary of the Weizmann Institute of Science. The stamp depicts an atom "flowering" on a test-tube plant.*




Over 100 new types of economically useful plants have been produced by mutation breeding. Of these, 69 came from X-ray treatment, 18 from gamma rays, and 13 from neutrons. Each type has some unique effects and is useful for different plants and different purposes.

One of the advantages of mutation breeding is that it speeds up the time required for the breeding program. This is because a number of mutations are produced at once. Conventional cross breeding usually takes several generations longer because the desirable gene has to be transferred to the commercial variety from another and often less desirable type. (Most mutations are not desirable and a considerable amount of selection is involved.)

Another advantage concerns a phenomenon called linked genes: The desirable characteristic may be controlled by a gene located on the same chromosome with one or more genes that cause undesirable characteristics. It is difficult with normal breeding techniques to separate such linked genes located close together on the chromosome. This is easier in mutation breeding. In effect the desired gene is freed from its unwanted associates.

High-energy radiation can also be used to preserve foodstuffs, although this technique will probably be used in the immediate future only as a supplement to the conventional methods of heating and freezing, or in places where refrigeration is not readily available. "Pasteurizing" with radiation to destroy most but not all of the microbes in meat, vegetables, or fruit can be accomplished with less than 5% of the dosage required for "sterilizing" with radiation. In addition such treatment does not alter appreciably the flavor or texture (as does sterilization) so that it could be used to prolong the shelf life of many fresh foods.

An ingenious application of the atom in agriculture concerns the screwworm fly. This

insect pest lays its eggs in the open wounds of livestock and the burrowing maggots inevitably kill or disable the animal. The entomologists involved in this scheme used the following approach. In the late 1950s some two billion radiation-sterilized screwworm flies were deliberately released from airplanes over Florida, Georgia, and Alabama at a rate of some fifty million weekly. Soon the area was smothered with sterile flies and the number of eggs that hatched (from normal, unirradiated native flies) rapidly fell to zero. This program was conducted for some 18 months and in that time the insect pest was eliminated in that area of the United States.

Indeed, one can say that the radioisotope, particularly when used as a tracer or radiation source, has become an indispensable servant to all phases of agricultural research.

## RADIOISOTOPES IN SPACE

Radioisotope thermoelectric generators to provide auxiliary power systems were explored jointly by the U. S. Atomic Energy Commission (AEC) and the National Aeronautics and Space Administration (NASA). These systems, designated SNAP (*S*ystems for *N*uclear *A*uxiliary *P*ower) are compact, lightweight, and reliable sources of electric power for remote area application.

The radioisotope generator thermoelectric elements produce electricity directly from the heat created by the decay of a radioisotope. A typical thermoelectric element as used in a radioisotope generator consists of a positive


*Country: Republic of Togo. Year: 1969. Colors: dark blue and multicolored. Denomination: 60 francs. Subject: Part of a set commemorating man's first moon landing.*

component and a negative component. For the positive components the flow of electrons is toward the hot junction. For the negative components the flow of electrons is away from the hot junction. The name RTG (*R*adioisotope *T*hermoelectric *G*enerator) is frequently given to radioisotope generators that use thermoelectric elements to produce electricity.

The RTG consists of four basic components: a shell or housing, a heat shield or insulation, the energy conversion elements, and the radioisotope fuel capsule. The outer shell is usually a metal case designed to protect the RTG from exposure to its operational environment (e.g., outer space, the polar regions, underwater, etc.). This shell also serves additionally as a radiator of "waste heat".


*Country: Republic of Togo. Year: 1964. Colors: yellow, green, and violet. Denomination: 20 francs. Subject: International Quiet Sun Year (IQSY). In the design are several spacecrafts launched by the United States. The Nimbus weather satellite (left) uses a radioisotope power generator to supplement its solar cell electric power supply*

The principle of RTG operation is simple. Essentially all the nuclear radiations emitted by the decay of the alpha emitting radioisotopes are absorbed within the fuel capsule itself. As these radiations are absorbed, the capsule material is heated and this heat flows away from the hot fuel capsule and through an array of thermoelectric elements, which convert a portion of this heat directly into electricity. However, because of the low-

*Country: United States. Year: 1969. Colors: multicolored. Denomination: 10 cents. Subject: Man's first moon landing. The Apollo 11 astronauts carried two plutonium-238 radioisotope heaters to the moon and used them for their Early Apollo Scientific Experiment Package (EASEP). The Apollo 12 crew and all subsequent lunar explorers have deployed SNAP-27 radioisotope power generators for their Apollo Lunar Scientific Experiment Packages (ALSEPs).*


energy conversion efficiencies associated with present-day thermoelectric elements, only some 5 or 10% of the total heat passing through these elements is actually converted into electricity. The remaining amount of heat flows to the outer shell of the RTG, where it is radiated away to space as "waste heat". The radiator rejects waste thermal energy and *not* nuclear radiation.

In June 1961 a Department of Defense Transit navigation satellite was placed into Earth orbit. The satellite carried a radioisotope thermoelectric generator on board as a supplementary source of electricity for its communication system. The auxiliary nuclear power system was called SNAP-3A and it had a power output of 2.7 watts (electric) and was fueled with plutonium-238. The successful launching marked the first use of atomic electric power in space by the United States. Since that time other Transit satellites have used improved radioisotope generators (the SNAP-9A device) and a NASA Nimbus weather satellite has flown with the SNAP-19 on board. The Nimbus weather satellites provide useful meteorological information. The early Nimbus spacecraft were powered exclusively by solar cells. However, Nimbus 3, launched in May 1969, carried a pair of radioisotope power generators to supplement the solar cell electric power system. In this way the SNAP-19 device has extended the useful mission lifetime of the Nimbus weather satellite.

In 1969 the Apollo 11 astronauts, on mankind's first voyage to the moon, set up the *E*arly *A*pollo *S*cientific *E*xperiment *P*ackage (EASEP) at their Sea-of-Tranquility base. Two 15-watt (thermal) plutonium-238 heaters were used to keep the EASEP operating during the long lunar night, which is approximately two earth weeks in duration. The Apollo 12 astronauts and later Apollo crews have their *A*pollo *L*unar *S*cientific *E*xperiment *P*ackages (ALSEP) powered by SNAP-27 devices. The SNAP-27 uses plutonium-238

as its fuel and creates about 70 watts of electric power. The SNAP-27 will continue to power many valuable lunar experiments long after the astronauts themselves have left the lunar surface.

Space missions of the late 20th and early 21st centuries will require even larger radioisotope power generators. The radioisotope has just begun its role in helping mankind explore the vast regions of space.

## NUCLEAR EXPLOSIVES

An atomic bomb is one whose energy comes from the *fission* (splitting apart) of heavy elements such as uranium or plutonium. When an atomic bomb is "ignited", more and more neutrons are released in an uncontrolled chain reaction. These neutrons produce many fissions in a very short period of time. Since so many nuclei of uranium-235 or plutonium-239 are fissioned, very large amounts of energy are released, creating extremely high temperatures that cause the bomb materials to vaporize; very large pressures are developed and a powerful explosion results. This is the fundamental principle of the fission (atomic) bomb.

The world's first atomic bomb was developed by the United States during World War II through a special, super-secret organization called the "Manhattan Project", which was under the command of Major General Leslie R. Groves. On July 16, 1945, at 5:30 a.m., the world's first atomic explosion occurred at Alamogordo, New Mexico. The

*Country: The United Nations. Year: 1964. Colors: dark brown and dark red. Denomination: 5 cents. Subject: The Nuclear Test Ban Treaty.*

"Trinity" explosion, as it was code-named, was built and developed at the Los Alamos Scientific Laboratory in New Mexico, and it marked the first use of plutonium. On August 6 (Japanese time) 1945 the first atomic bomb ever to be used in warfare was dropped on Hiroshima, Japan. This explosion was announced as having a yield of about 20 kilotons. One kiloton (kt) is the amount of a nuclear explosive equivalent to the detonation of 1000 tons of TNT. On August 9 (Japanese time) 1945 a second atomic bomb was dropped on the Japanese city of Nagasaki. The war between the United States and Japan came to a swift conclusion on August 14, 1945. In 1946 two more nuclear tests were conducted as part of the Manhattan Project at the Bikini Atoll in the Pacific Ocean. On January 1, 1947, the U. S. Atomic Energy Commission took over responsibility for weapons testing and development. (The research and development programs of the AEC have now been absorbed by the Energy Research and Development Administration.)

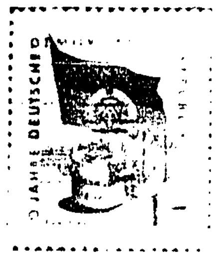
*Country: Japan. Year: 1949. Color: green. Denomination: 8 yen. Subject: The naming of Nagasaki as the International City of Culture. Issued as a companion to the following stamp.*

The development of American nuclear explosive technology progressed until the AEC test-fired a *thermonuclear* device, code-named "Mike", on November 1, 1952 (local time) at Eniwetok Atoll in the Pacific Ocean. Thermonuclear refers to the process or processes in which very high temperatures are used to bring about the *fusion* (joining together) of light nuclei. Fusion is the nuclear process whereby the nuclei of light elements, especially the isotopes of hydrogen called deuterium and tritium, combine to form the nucleus of a heavier element with the subsequent release of substantial amounts of energy. The nuclear explosion based essentially on the fusion reaction is commonly called a

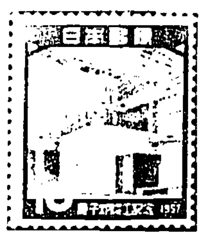
*Country: Japan. Year: 1949. Color: yellow brown. Denomination: 8 yen. Subject: The naming of Hiroshima as the City of Eternal Peace.*


"hydrogen bomb". A fission bomb is used to trigger a hydrogen bomb.

Thus there are essentially two types of nuclear explosives: One in which the energy is produced by nuclear fission and one in which the energy is mainly produced by nuclear fusion.



*Country: German Democratic Republic (East Germany). Year: 1959. Color: black, red, and orange yellow. Denomination: 1 mark. Subject: The 10th anniversary of the German Democratic Republic. East Germany's first nuclear reactor is in the design.*



*Country: Japan. Year: 1957. Color: dark purple. Denomination: 10 yen. Subject: Japan's first nuclear reactor at Tokai-Mura.*


*Country: Belgium. Year: 1961. Color: red lilac. Denomination: 3 francs. Subject: European Nuclear Research Center at Mol. Belgium. The core of the Belgian Reactor 3 is the design. Issued as a companion to the Belgian stamp on the top of page 64.*

## HOW A NUCLEAR REACTOR OPERATES

A nuclear reactor is simply a device in which a self-sustained neutron chain reaction can take place in a controlled manner. The basis for energy production in a reactor is the process of nuclear fission. This splitting of a heavy atomic nucleus is accompanied by the release of a large amount of energy—approximately 200 million electron volts for uranium-235—and, in general, one or more neutrons. To maintain a stable self-sustained chain reaction in a nuclear reactor, every fission must produce exactly one neutron that eventually succeeds in causing another fission reaction. Under this condition the number of fissions occurring per unit time within the reactor is constant and the reactor is described as critical.

In general, reactors are controlled by regulating the neutron population within the central part of the reactor, which is called the core. The control rods contain neutron-absorbing materials such as boron or hafnium. These control rods regulate and control the power level of the reactor. Neutrons, absorbed by the control rods, cannot cause other fission reactions.

The use of a reactor often determines its power output requirements and therefore its temperature characteristics. For example, research reactors are frequently operated at such low power levels that they usually do not require a cooling system. The characteristic operating temperature for this "zero power" reactor is then fairly low and usually

less than 200°F (93°C). On the other hand, reactors used for electric power production or desalting must operate at high power levels, since the heat that is carried away from the core by the coolant is their primary "product". Consequently, power reactors have high operating temperatures, often in excess of 500°F (260°C).

Although there are many applications for the heat generated within, and the radiations emitted by, a nuclear reactor, this booklet will be limited to a discussion of the following reactor applications: (1) naval propulsion systems and (2) electric power production systems.

## REACTORS AT SEA

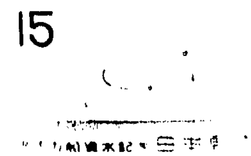
### Naval

Before the first nuclear submarine became a fact, the submarine was at best a hybrid. It was a small surface ship that could submerge for very short periods of time. In 1950 the submergence time and the average submerged speed of a submarine were not much greater than those of submarines in use 30 years earlier.

Pre-nuclear submarines using traditional fuels required oxygen to operate and to keep their crews alive. Once submerged, that oxygen supply was cut off. The boat was dependent for its power on short-lived electric batteries, its crew dependent upon the air trapped within the hull or carried in bottles.

The nuclear reactor eliminated (1) the combustion engines that limited a submarine's range and speed, (2) the need for a large amount of space to store oil, and (3) the necessity for surfacing to recharge batteries.

The introduction of the nuclear-powered submarine, with the launching of the USS *Nautilus*, transformed undersea warfare tactics and national defense strategies. The compactness of the nuclear reactor and its fuel coupled with the fact that the reactor—unlike the conventional diesel engine—requires no oxygen for operation, means that nuclear powered submarines can operate submerged, at high speeds for very long periods of time. For example, fleet ballistic submarines, such as the USS *George Washington*, usually remain on submerged patrol for 60 to 70 days at a time.




*Country: Japan. Year: 1969. Colors: black, gray, pink, and blue. Denomination: 15 yen. Subject: Nuclear-powered merchant ship* Mutsu.

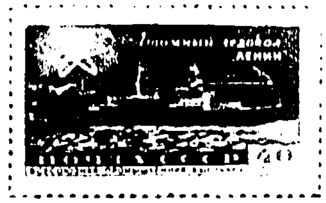
The advantages of nuclear power in providing high speed and virtually unlimited propulsion endurance have also proved of great value in surface warship applications. Today the U. S. Navy has a nuclear-powered fleet consisting of 105 submarines, 1 deep submergence research vessel, and 6 surface ships.

Of particular importance is the development of long-life reactor cores for naval use. At present, cores are being installed in the Navy's nuclear ships that will provide for over 10 years of normal operation. This means that a submarine could travel some 16 times around the world without refueling—a distance of more than 400,000 miles!

Nuclear submarines have not been the only vessels to demonstrate by their extended operations the value and capability of nuclear propulsion at sea. In 1964 the carrier *Enterprise*, the cruiser *Long Beach*, and the frigate


*Country: The United States. Year: 1959. Color: bright greenish blue. Denomination: 4 cents. Subject: The conquest of the North Pole by land in 1909 by Admiral Peary and by sea in 1958 by the USS* Nautilus, *the first nuclear-powered submarine.*

*Country: Russia (USSR). Year: 1958. Colors: black, bistre, red, and greenish blue. Denomination: 40 kopecks. Subject: Nuclear-powered icebreaker* Lenin.



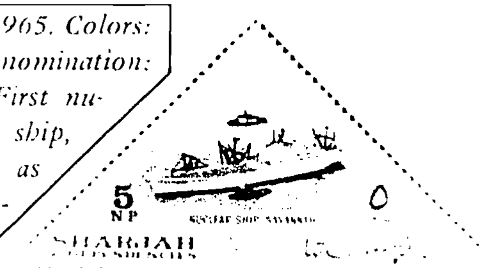
*Bainbridge* participated in Operation Sea Orbit, a 65-day cruise around the world. This "nuclear task force", completely free of refueling or logistic support of any kind, successfully covered over 30,000 miles of ocean.

Nuclear attack submarines of new design, including the electric drive submarine *Glenard P. Lipscomb* and the Los Angeles Class of high-speed attack submarines, are being developed. Work has also started on the Trident Class of ballistic missile firing submarines. In surface ships the Nimitz Class of two reactor carriers is under construction as are the California and Virginia Classes of nuclear powered frigates.

Civil Maritime

The nuclear reactor has not been used at sea exclusively for warships. On October 15, 1956, President Eisenhower directed the

*Country: Sharjah. Year: 1965. Colors: brown and blue green. Denomination: 5 naye paise. Subject: First nuclear-powered merchant ship, the NS* Savannah. *Issued as part of a set commemorating transportation.*



Department of Commerce and the Atomic Energy Commission to develop and construct the world's first nuclear-powered merchant ship, the NS *Savannah*. The *Savannah* was small in size (595 feet long and displacing some 22,000 tons) and intended to function as a nuclear demonstration model. This unique ship with its limited cargo space crossed the oceans of the world from 1962 and 1971, constantly demonstrating the safety and practicality of nuclear power for merchant ships. In 1971, because of heavy dollar losses incurred by the ship's successful but uneconomic operations, the *Savannah* was retired. She is now in Savannah, Georgia.

Nonetheless, the *Savannah* was a flawless success. In nearly 10 years of sailing she never had an accident and never developed problems with radioactivity. Thus she served her purpose well as a demonstration model of the potential economic advantages of nuclear propulsion for commercial vessels. Two of these advantages are: (1) availability of more cargo space by eliminating fuel storage areas; and (2) improved ship utilization, due to higher cruising speeds and the elimination of the need for frequent refueling. Therefore, based on the valuable experience acquired from the operation of the *Savannah*, future nuclear merchant vessels such as large container ships or tankers can be designed to take advantage of nuclear propulsion and yet be economically competitive with conventionally fueled ships.

Other nations have also used the nuclear reactor to propel ships. For example, in 1957

the Soviet Union launched the nuclear-powered icebreaker, *Lenin*, which was the world's first nuclear surface ship to put to sea. The *Lenin* is approximately 440 feet long, displaces some 16,000 tons, and is powered by three pressurized-water reactors. In 1968 construction was completed on the Federal Republic of Germany's first nuclear-powered merchant ship, the *Otto Hahn*, which is a 15,000-ton ore carrier powered by a pressurized-water reactor. Finally, Japan's first nuclear-powered merchant vessel, the 8,000-ton research cargo ship *Mutsu*, was launched in 1969.

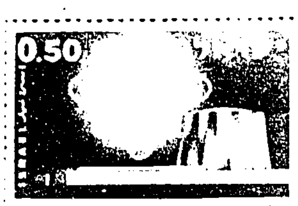
Many maritime nations are investigating future applications of the nuclear reactor for merchant shipping. These investigations include such concepts as a fleet of nuclear-powered freighter or tanker submarines, high-speed nuclear passenger liners, and highly automated nuclear-powered container vessels.


*Country: Belgium. Year: 1961. Color: dark blue green. Denomination: 40 centimes. Subject: Belgian Reactor 2*

## REACTORS FOR ELECTRIC POWER PRODUCTION

From the dawn of history man has sed energy. Without energy he cannot survive. In the beginning man had only the energy derived from his food; this "biological" energy allowed him to perform work with the power of his own muscles. In time he discovered the existence of other energy sources and learned to control these sources so that the power of his own muscles was greatly enhanced and he was able to accomplish more and more work. Progress in man's discovery and application of energy is continuing even today. Modern man lives in a highly complex, highly technical socie y, which is dependent for its functioning and perhaps its very survival upon energy, and in particular upon electricity.

When a nuclear reactor is used to generate electricity, the system is called a nuclear power plant. In this system the thermal energy necessary to generate the steam that

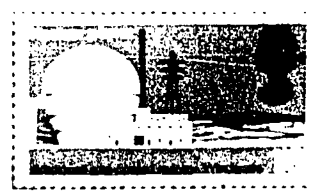



*Country: Israel. Year: 1960. Colors: red, blue, and black. Denomination: 50 agorot. Subject: The installation of the first nuclear reactor in Israel.*

*Country: Russia (USSR). Year: 1956. Colors: multicolored. Denomination: 60 kopecks. Subject: The first Russian atomic electric station.*


drives the turbogenerator, which produces electricity is provided by means of a controlled neutron fission chain reaction. In other words, in a nuclear power plant the nuclear reactor replaces the conventional fossil-fuel-fired boiler of the steam power plant. With the nuclear reactor used as the source of heat the thermal energy is released in a clean, efficient manner and the world's rapidly dwindling supply of precious fossil fuels is conserved for other, more important applications. Of course, electricity is electricity, regardless of whether it is generated by falling water (a hydroelectric plant), burning coal (a conventional steam plant), or splitting atoms (a nuclear power plant). Just a few years ago commercial nuclear power was simply an exotic idea of the scientific community. Today the atom is working around the world to help satisfy man's growing need for electricity.

*Country: Great Britain. Year: 1966. Colors: multicolored. Denomination: 1 shilling and 6 pence. Subject: Advanced gas-cooled Windscale reactor. Part of a set honoring British technology.*



## THE INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA)

On December 8, 1953, President Dwight D. Eisenhower proposed to the United Nations the establishment of an agency devoted exclusively to the peaceful uses of the atom.


*Country: Belgium. Year: 1958. Color: red brown. Denomination: 10 francs. Subject: International Atomic Energy Agency. Part of a set honoring various international agencies related to the United Nations.*

Before this international agency could be organized, the United States initiated its own action to implement the spirit of President Eisenhower's proposal by creating the "Atoms-for-Peace" Program in 1955. Through this program the United States exchanges

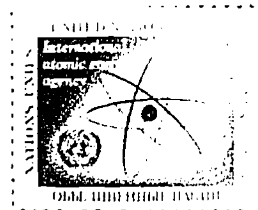
*Country: Federal Republic of Cameroun. Year: 1967. Colors: emerald and ultramarine. Denomination: 50 francs. Subject: International Atomic Energy Agency.*

information on the peaceful uses of atomic energy with other nations and groups of nations and sells nuclear fuels abroad for both research and power reactors. Thirty-four agreements for cooperation that are in effect with other nations or groups of nations provide the framework for cooperative activities

carried out under the program. An important part of each agreement is the establishment of procedures to assure that the materials or equipment supplied will not be diverted from peaceful to military purposes.

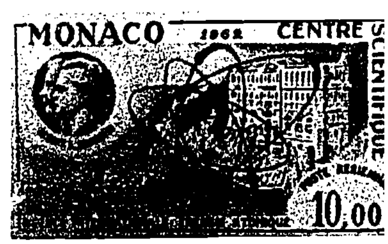
Nuclear information was also freely exchanged by scientists from around the world at the International Conferences on Peaceful

*Country: The United Nations. Year: 1958. Color: olive. Denomination: 3 cents. Subject: International Atomic Energy Agency.*



Uses of Atomic Energy that the United Nations conducted in Geneva, Switzerland, in 1955, 1958, 1964, and 1971. The 1955 Geneva Conference is particularly significant, since it represented the first time in man's "Nuclear Age" (which began on December 2, 1942) that scientists from many nations met

*Country: Monaco. Year: 1962. Colors: bistre, violet, and blue. Denomination: 10 francs. Subject: The IAEA laboratory in Monaco.*




openly to discuss nuclear energy. At the 1955 and subsequent Geneva Conferences a great deal of previously classified information was released for public use.

The International Atomic Energy Agency (IAEA), officially created in 1957, is an autonomous intergovernmental organization

that, "under the aegis of the United Nations, is responsible for international activities concerned with the peaceful uses of atomic energy".

The objectives of the IAEA are ". . . to seek to accelerate and enlarge the contributions of atomic energy to peace, health and prosperity throughout the world" and ". . . to ensure that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose".

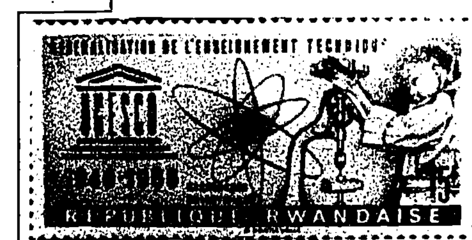

*Country: Russia (USSR). Year: 1962. Colors: black, orange, red, and ultramarine. Denomination: 6 kopecks. Subject: In the design is the word "peace" in ten languages and a large diagram of an atom superimposed on a map of Russia. Part of a set honoring the concept of "Atoms for Peace".*

The IAEA Headquarters is located in Vienna, Austria, and more than 100 nations are members. In its daily activities the IAEA fosters and encourages the peaceful and beneficial uses of nuclear energy in scientific research and application (for electric power, agriculture, biology, medicine, hydrology, and industry) throughout the world. Through its safeguards system the IAEA seeks to prevent the harmful global consequences that would result if nuclear material or equipment, intended for peaceful purposes, was diverted to

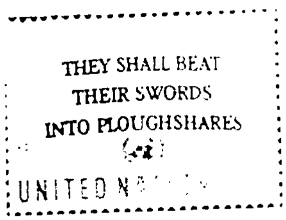
military applications. The IAEA also functions as a guide and advisor by helping the developing nations of the world plan and establish nuclear programs and safety standards for various nuclear operations.

Therefore, the programs of the IAEA enter many scientific fields, extend to many nations, and use many techniques. For example, the IAEA operates laboratories in Vienna and Seibersdorf, Austria, and a third in

*Country: The Republic of Rwanda. Year: 1966. Colors: red lilac and dark blue. Denomination: 15 francs. Subject: The role of the atom in modern industry and technology. Part of a set commemorating the twentieth anniversary of UNESCO (the United Nations Educational, Scientific and Cultural Organization). The stamp features the UNESCO emblem, an atomic symbol, and a laborer operating a power drill.*




Monaco. At the two laboratories in Austria, work is done for the safeguards program in the fields of meteorology and chemical analysis and for the agricultural program in the research and training areas. The laboratory in Monaco, established in 1961 at the Oceanographic Institute, studies such topics as the development of reference methods and techniques for investigating the effect of radioactivity on marine life and the fate and effects of radioactivity in the sea.




*Country: The United Nations. Year: 1967 Colors: multicolored. Denomination: 6 cents. Subject: The U. N. General Assembly's resolutions for the suspension of nuclear weapons tests and for disarmament.*

The majority of the IAEA's members are developing nations and the Agency's most direct channel of assistance to such countries is its technical assistance program, in which expert scientific advisors, equipment grants, loans, and training opportunities are provided. In addition, the Agency's research contract program and its programs of scientific meetings and technical information compilation and dissimination benefit its entire membership, including the U. S. All its valuable work is accomplished by the IAEA in close cooperation with many other organizations, both national and international. From the beginning, the U. S. has been the IAEA's largest contributor and one of its most influential members.

One of the IAEA's most important functions is to establish and ensure through its safeguards system that nuclear material or equipment intended for peaceful applications is not diverted to military purposes. As of June 30, 1972, IAEA safeguards have been applied to almost 250 nuclear facilities of all types around the world, including some 130 nuclear reactors. Any nuclear project that has been set up with IAEA assistance must accept IAEA safeguards; this system is also applied upon request. In 1959, Japan became the first

*Country: Afghanistan. Year: 1958. Color: blue. Denomination: 50 pouls. Subject: "Atoms-for-Peace" Program.*


nation to accept IAEA safeguards over a single facility, and in 1968 Mexico became the first country to place its entire nuclear program under IAEA safeguards.

The IAEA safeguards system is one of strict statistical accounting that involves four basic steps: (1) nuclear science experts from the IAEA review the design of the nuclear facility to be safeguarded solely to determine if it can be effectively controlled; (2) the nation requesting the IAEA safeguards is required to keep a detailed record of the facility's operation and of its nuclear material inventory; (3) the government of the country must supply periodic reports to the IAEA concerning those nuclear facility records maintained as part of Step Two of the safeguards system; (4) the IAEA maintains the right to send inspectors for on-the-spot checks of the safeguarded facility. It is this complex program of accurate data collection and evalu-

*Country: Switzerland. Year: 1958. Colors: yellow, red, and blue. Denomination: 40 centimes. Subject: Second International Conference on Peaceful Uses of Atomic Energy conducted by the United Nations in Geneva, Switzerland.*

ation by which the IAEA is able to detect accidental loss or intentional diversion of nuclear materials.

In summary, the IAEA with all of its diverse and beneficial activities may be called a truly worldwide organization dedicated to the concept of "man helping man to utilize the atom in peaceful, productive ways".

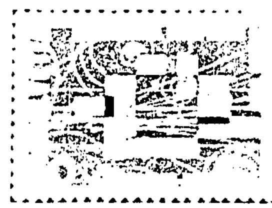
## CERN

The "Conseil Européen pour la Recherche Nucléaire" (European Council for Nuclear Research) is an advanced research organization with its headquarters and main laboratory at Meyrin, near Geneva, Switzerland. CERN, as it is called, has 12 European nations as members who conduct fundamental research through the cooperative pooling of scientific efforts and financial support. These nations are Austria, Belgium, Denmark, Federal Republic of Germany, France, Greece, Italy, The Netherlands, Norway, Sweden, Switzerland, and the United Kingdom.

It is interesting to note that the CERN site itself involves some 107 acres in Switzerland and an adjacent 103 acres in France. This makes CERN the first international nuclear organization to actually cross an international boundary and erase the visible fences.

After World War II the nations of Western Europe were faced with the possibility of losing many of their scientists to other countries since so little effort at that time could be devoted to fundamental research. Therefore,

*Country:* Switzerland. *Year:* 1966. *Colors:* black and multicolored. *Denomination:* 50 centimes. *Subject:* European Organization for Nuclear Research (CERN). The design contains a background of atomic particle tracks upon which are superimposed the flags of the member states.

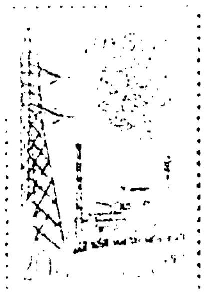


concerned with assuming a permanently inferior scientific position, it was suggested in 1948 that an international center, dedicated to fundamental research, be created by pooling scientific efforts and financial resources, and so, in February 1952, CERN was created.

CERN is independent of all other national and international organizations, although it cooperates and coordinates its efforts as far as possible with the various laboratories and institutes located in member states. It is governed by a Council, which is composed of two delegates (usually one scientist and one administrator) from each member state. Each state has one vote in this Council.

From its very beginning, CERN was dedicated to the joint pursuit of pure, fundamental research. The main interest of CERN is the science of sub-nuclear physics. But to perform these studies the particles of subnuclear physics (e.g., the neutrino, the antineutrino, the muon, the antimuon, etc.) must first be produced and sorted.

The most readily available and the simplest of the larger elementary particles is the proton. If its structure is to be studied, it



Country: France. Year: 1959. Colors: red brown and bright carmine. Denomination: 20 francs. Subject: Marcoule Atomic Center. Part of a set honoring French technical achievements.

must be taken apart. At CERN this is accomplished using powerful particle accelerators. In these machines the protons are given very high energies and then are made to strike a target, producing secondary particles, which are then separated and examined (often by using these secondary particles as projectiles against still other targets). In the end the theoretical physicist examines the experimental results and attempts to unravel the mystery of the basic structure of matter.

# Reading List

Atomic Energy

*Atomic Energy*, Irving Adler, The John Day Company, Inc., New York, 1971, 47 pp., $2.97. Grades 4-6.

*Atomic Energy*, Matthew Gaines, Grosset and Dunlap, Inc., New York, 1970, 159 pp., $3.95. Grades 8-12.

*Atompower*, Joseph M. Dukert, Coward-McCann, Inc., New York, 1962, 127 pp., $3.95. Grades 5-8.

*Atoms for Peace* (revised edition), David O. Woodbury, Dodd, Mead and Company, New York, 1965, 275 pp., $4.50.

*Atoms Today and Tomorrow* (4th edition), Margaret O. Hyde, McGraw-Hill Book Company, New York, 1970, 160 pp., $4.50.

*Inside the Atom* (revised edition), Isaac Asimov, Abelard-Schuman Ltd., New York, 1966, 197 pp., $4.95. Grades 7-10.

*Man and Atom: Shaping a New World Through Nuclear Technology*, Glenn T. Seaborg and William R. Corliss, E. P. Dutton and Company, Inc., New York, 1971, 320 pp., $8.95.

*Man and Atom: The Uses of Nuclear Energy*, Frank Barnaby, Funk and Wagnalls, Inc., New York, 1971, 216 pp., $6.95.

*The New World of the Atom* (revised edition), James Stokeley, Ives Washburn, Inc., New York, 1970, 333 pp., $6.95. Grades 8-12.

*The Peaceful Atom*, Bernice Kohn, Prentice-Hall, Inc., Princeton, New Jersey, 1963, 72 pp., $3.75. Grades 4-6.

*Peacetime Uses of Atomic Energy* (revised edition), Martin Mann, The Viking Press, New York, 1961, 191 pp., $3.75 (hardback); $1.65 (paperback). Grades 9-12.

*Secret of the Mysterious Rays: The Discovery of Nuclear Energy*, Vivian Grey, Basic Books, Inc., New York, 1966, 120 pp., $3.95. Grades 4-8.

*The Useful Atom*, William R. Anderson and Vernon Pizer, The World Publishing Company, New York, 1966, 185 pp., $5.95.

## Philately

*The Complete Guide to Stamp Collecting* (second edition), Prescott H. Thorp, Minkus Publications, Inc., New York, 1971, 200 pp., $3.95.

*Linn's Stamp News* (weekly philatelic newspaper), Amos Press, Inc., Sidney, Ohio, $6.50 per year.

*Minkus New 1975 World Wide Stamp Catalogs*, Volumes I and II, Minkus Publications, Inc., New York, @$15.95.

*Scott's New Handbook for Philatelists*, Simon and Schuster, Inc., New York, 1967, $5.00.

*Scott's Standard Postage Stamp Catalogue: The Encyclopedia of Philately*, Scott Publishing Company, New York, 1975, 3 volumes, $39.00.

*Western Stamp Collector* (weekly philatelic newspaper), Van Dahl Publications, Inc., Albany, Oregon, $4.75 per year.

The following publications are available from the American Topical Association, Milwaukee, Wisconsin:

*Stamp Publication Handbook*, numbers HB31 ($4.00), HB40 ($5.00), and HB74 ($3.00) on Atomic Energy and Radiology.

*Topical Time* issues number 108, 109, and 134 (@$1.00); issue number 145 (@$1.25).

*Stamps Magazine* (weekly), H. L. Lindquist Publications, New York, $5.90 per year.

# Appendix-List of Nuclear Stamps

This listing is alphabetical by issuing country. The catalog numbers are from the 1975 edition of *Scott's Standard Postage Stamp Catalogue* and the *Minkus New 1973 World Wide Stamp Catalogs*. These numbers are the copyrighted property of the Scott Publishing Company and Minkus Publications, Inc., and are presented here with permission of those companies.

An entry with catalogue numbers such as 462-63 and 422-23 means that there are *two* stamps for that entry. An entry with catalogue numbers such as 538-40 and 1435-37 means that there are three stamps for that entry.

A number and asterisk preceding the stamp's name indicate that it has been used as an illustration in this booklet; the number is the page on which the stamp may be found.

Please note that this list of nuclear stamps is *not* complete.

| Country of Issue and Description | Year of Issue | Scott Catalogue Number | Minkus Catalogue Number |
|---|---|---|---|
| AFGHANISTAN<br>Pierre & Marie Curie | 1938 | RA2 | 216 |
| 71*AFGHANISTAN<br>Atoms for Peace | 1958 | 462-63 | 422-23 |
| ALGERIA<br>Atomic Symbol, Educational Symbol and Blackboard | 1970 | 450 | 629 |
| ARGENTINA<br>Atucha Nuclear Center | 1969 | C116 | 1278 |
| 66*BELGIUM<br>International Atomic Energy Agency | 1958 | C20 | 1306 |
| 56,64*BELGIUM<br>Atomic Research Center at MOL | 1961 | 538-40 | 1435-37 |

| Country of Issue and Description | Year of Issue | Scott Catalogue Number | Minkus Catalogue Number |
|---|---|---|---|
| BELGIUM<br>Atom Symbol and Retort (Atomic Research Center at MOL) | 1966 | 623 | 1617 |
| BRAZIL<br>Symbols of Atomic Energy, Agriculture, and Industry | 1963 | 963 | 1161 |
| BULGARIA<br>Pierre Curie | 1957 | 957 | 1145 |
| CAMEROUN<br>Pierre and Marie Curie | 1938 | B1 | 162 |
| 66*CAMEROUN<br>International Atomic Energy Agency | 1967 | 458 | 575 |
| 41*CANADA<br>Atoms for Peace; Douglas Point Reactor | 1966 | 449 | 546 |
| 24*CANADA<br>Ernest Rutherford | 1971 | 534 | 642 |
| CENTRAL AFRICAN REPUBLIC<br>Nimbus Weather Satellite (Radioisotopes in Space) | 1965 | C27 | 197 |
| 16*CENTRAL AFRICAN REPUBLIC<br>Marie Curie | 1968 | C57 | 293 |
| CEYLON<br>Uranium atom diagram | 1969 | 436 | 426 |
| CHINA (NATIONALIST)<br>Nuclear Reactors | 1961 | 1331-33 | 479-81 |
| CHINA (NATIONALIST)<br>Nimbus III Satellite (Radioisotopes in Space) | 1970 | 1652 | 822 |

| Country of Issue and Description | Year of Issue | Scott Catalogue Number | Minkus Catalogue Number |
|---|---|---|---|
| CONGO, DEMOCRATIC REPUBLIC OF (ex-Belgian) (Country renamed Zaire in 1971) Atom Symbol, 1st African Reactor | 1964 | 472-79 | 569-76 |
| CONGO, PEOPLE'S REPUBLIC OF (ex-French) Atom Symbol and Grain | 1966 | C38 | 290 |
| CUBA Pierre and Marie Curie | 1938 | B1-2 | 413-14 |
| CZECHOSLOVAKIA Nuclear Reactor | 1958 | 861 | 1216 |
| 6*CZECHOSLOVAKIA Nuclear Rockets | 1963 | 1173.74 | 1526, 27 |
| CZECHOSLOVAKIA Atom Diagram and Head | 1963 | 1210 | 1569 |
| CZECHOSLOVAKIA Nuclear Power Plant | 1964 | 1265 | 1624 |
| CZECHOSLOVAKIA Joachimsthal, where pitchblende was discovered | 1966 | 1413 | 1777 |
| DAHOMEY Pierre and Marie Curie | 1938 | B2 | 176 |
| DAHOMEY Nimbus Weather Satellite (Radioisotopes in Space) | 1965 | 197 | 340 |
| 11*DANZIG Wilhelm Roentgen | 1939 | 240 | 409 |
| 28*DENMARK Niels Bohr | 1963 | 409-10 | 584-85 |
| FINLAND Nuclear Data Conference | 1970 | 494 | 698 |

| Country of Issue and Description | Year of Issue | Scott Catalogue Number | Minkus Catalogue Number |
|---|---|---|---|
| FINLAND<br>Strategic Arms Limitation Talks (US USSR) | 1970 | 501 | 709 |
| 17*FRANCE<br>Pierre and Marie Curie | 1938 | B76 | 574 |
| FRANCE<br>13*Antoine Henri Becquerel | 1946 | B202 | 884 |
| 74*FRANCE<br>Marcoule Atomic Center | 1959 | 921 | 1410 |
| 40*FRANCE<br>Nuclear Reactor | [illegible] | 1135 | 1731 |
| 16*FRANCE<br>Marie Curie | 1967 | 1195 | 1806 |
| FRANCE<br>Nuclear Submarine *Le Redoutable* | 1969 | 1259 | 1890 |
| FR. EQUATORIAL AFRICA<br>Pierre and Marie Curie | 1938 | B1 | 93 |
| FRENCH GUIANA<br>Pierre and Marie Curie | 1938 | B3 | 208 |
| FRENCH GUINEA<br>Pierre and Marie Curie | 1938 | B2 | 196 |
| FRENCH INDIA<br>Pierre and Marie Curie | 1938 | B6 | 133 |
| FRENCH POLYNESIA<br>Pierre and Marie Curie | 1938 | B5 | 146 |
| FRENCH SUDAN<br>Pierre and Marie Curie | 1938 | B1 | 195 |
| GABON<br>Uranium Mining | 1966 | 182 | 269 |
| GABON<br>International Atomic Energy Agency | 1965 | 216 | 32[illegible] |

| Country of Issue and Description | Year of Issue | Scott Catalogue Number | Minkus Catalogue Number |
|---|---|---|---|
| GERMANY, EAST Max Plar | 1950 | 63 | 153 |
| GERMANY, EAST Nuclear Explosion | 1950 | 73 | 164 |
| GERMANY, EAST Max Planck, Quantum Theory | 1958 | 383-84 | 552-53 |
| GERMANY, EAST Atomic Bomb | 1958 | 404-5 | 583-84 |
| 56•GERMANY, EAST Nuclear Reactor | 1959 | 465 | 656 |
| GERMANY, EAST Wilhelm Roentgen | 1965 | 753 | 1016 |
| GERMANY, EAST Marie Curie | 1967 | 937 | 1210 |
| GERMANY, WEST Wilhelm Roentgen | 1951 | 686 | 1366 |
| 7•GERMANY, WEST Atom Symbol and Globe | 1955 | 731 | 1433 |
| 32•GERMANY, WEST Nuclear Reactor, Fission | 1964 | 893 | 1666 |
| 19•GERMANY/BERLIN, WEST Max [illegible]nck | 1953 | 9N92 | 110 |
| GHANA Nuclear Explosion | 1962 | 116 | 298 |
| 22•GHANA Albert Einstein | 1964 | 190 | 377 |
| GIBRALTAR Nuclear Submarine HMS *Dreadnought* | 1967 | 197 | 203 |
| GREAT BRITAIN Dounreay Nuclear Reactor | 1964 | 413 | 520 |
| 65•GREAT BRITAIN Windscale Nuclear Reactor | 1966 | 469 | 570 |

| Country of Issue and Description | Year of Issue | Scott Catalogue Number | Minkus Catalogue Number |
|---|---|---|---|
| 6,8*GREECE Democritus Nuclear Center | 1961 | 716-17 | 957-58 |
| 29*GREENLAND Niels Bohr | 1963 | 57-58 | 73-74 |
| GUADELOUPE Pierre and Marie Curie | 1938 | B3 | 194 |
| HUNGARY Dubna Nuclear Institute | 1966 | 1763 | 2570 |
| INDIA Trombay Atomic Center | 1965 | 422 | 686 |
| INDIA Atomic Reactor, Homi Bhabha (scientist) | 1966 | 437 | 701 |
| INDIA Marie Curie | 1968 | 476 | 764 |
| INDOCHINA Pierre and Marie Curie | 1938 | B14 | 348 |
| INDONESIA Atom Diagram | 1962 | 578-80 | 1277-79 |
| 23*ISRAEL Albert Einstein | 1956 | 117 | 155 |
| 64*ISRAEL Nuclear Reactor | 1960 | 182 | 241 |
| ISRAEL Radioisotopes | 1968 | C45 | 447 |
| 47*ISRAEL Atom Diagram, Test Tube, Plant | 1969 | 400 | 490 |
| ITALY Amedeo Avogadro | 1956 | 714 | 1174 |
| 35*ITALY Enrico Fermi, First Nuclear Reactor | 1967 | 976 | 1455 |
| IVORY COAST Pierre and Marie Curie | 1938 | B2 | 197 |

| Country of Issue and Description | Year of Issue | Scott Catalogue Number | Minkus Catalogue Number |
|---|---|---|---|
| 54*JAPAN<br>Hiroshima, Nagasaki | 1949 | 465-66 | 498-99 |
| 56*JAPAN<br>Nuclear Reactor | 1957 | 638 | 730 |
| JAPAN<br>International Atomic Energy Agency | 1965 | 848 | 967 |
| 44*JAPAN<br>Medical X rays, Cobalt-60 Treatment | 1966 | B32-33 | 1020-21 |
| 60*JAPAN<br>Nuclear Merchant Ship *Mutsu* | 1969 | 991 | 1104 |
| JUGOSLAVIA<br>Atomic Accelerator, Generator, Nuclear Reactor | 1960 | 582-84 | 1181-83 |
| JUGOSLAVIA<br>International Atomic Energy Agency | 1961 | 596 | 1199 |
| KOREA, SOUTH<br>Nuclear [illegible] | 1962 | 349 | 360 |
| KOREA, SOUTH<br>Atom Diagram and Symbols of Progress | 1968 | 604 | 615 |
| KOREA<br>International Atomic Energy Agency | 1971 | 776 | 771 |
| KUWAIT<br>Atom Diagram and Symbols of Education | 1965 | 283-85 | 308-10 |
| LIBERIA<br>Atom Diagram and UN Emblem | 1970 | | 931 |
| MADAGASCAR<br>Pierre and Marie Curie | 1938 | B2 | 267 |

| Country of Issue and Description | Year of Issue | Scott Catalogue Number | Minkus Catalogue Number |
|---|---|---|---|
| MADAGASCAR<br>Nuclear Reactor | 1962 | 335 | 526 |
| MARTINIQUE<br>Pierre and Marie Curie | 1938 | [illegible] | 208 |
| MAURITANIA<br>Pierre and Marie Curie | 1938 | B[illegible] | 103 |
| MAURITANIA<br>International Atomic Energy Agency | 1967 | C6[illegible] | 390 |
| MONACO<br>Pierre and Marie Curie | 1938 | B24 | 206 |
| 67*MONACO<br>IAEA Oceanographic Institute | 1962 | C62 | 775 |
| 17*MONACO<br>Marie Curie | 1967 | 673 | 932 |
| NEW CALEDONIA<br>Pierre and Marie Curie | 1938 | B4 | 257 |
| NEW CALEDONIA<br>Nimbus Weather Satellite (Radioisotopes in Space) | 196[illegible] | C39 | 475 |
| 25*NEW ZEALAND<br>Ernest Rutherford | 1971 | 487-88 | 793-94 |
| NIGER<br>Pierre and Marie Curie | 1938 | B1 | 105 |
| 45*NIGER<br>Nuclear Medicine | 1966 | C66 | 308 |
| 45*NORWAY<br>Nuclear Medicine | 1931 | B4 | 192 |
| PAKISTAN<br>Nuclear Reactor | 1966 | 223 | 314 |
| PANAMA<br>Pierre and Marie Curie | 1939-49 | RA1-4,6-18, 24-27,30 | 341-62 |
| POLAND<br>Marie Curie | 1947 | 401 | 582 |

| Country of Issue and Description | Year of Issue | Scott Catalogue Number | Minkus Catalogue Number |
|---|---|---|---|
| POLAND<br>Marie Curie | 1947 | 410 | 590 |
| 11*POLAND<br>Dmitri Mendeleev | 1959 | 881 | 1216 |
| 22*POLAND<br>Albert Einstein | 1959 | 882 | 1217 |
| 17*POLAND<br>Marie Curie | [illegible] | 1154 | 1492 |
| POLAND<br>Atom Diagram and Book | 1964 | 1246 | 1587 |
| POLAND<br>Marie Curie | 1967 | 1518-20 | 1857-59 |
| POLAND<br>Marie Curie | 1969 | 1669 | 2014 |
| REUNION<br>Pierre and Marie Curie | 1938 | B4 | 210 |
| ROMANIA<br>Pierre Curie | 1956 | 1126 | 1808 |
| ROMANIA<br>Atom Symbol, Slide-rule, Caliper | 1957 | 1159-60 | 1856-57 |
| ROMANIA<br>Nuclear-powered Icebreaker *Lenin* (USSR) | 1959 | 1296 | 2013 |
| ROMANIA<br>Nuclear Reactor | 1960 | 1360 | 2092 |
| ROMANIA<br>Marie Curie | 1967 | 1944 | 2786 |
| ROMANIA<br>Atom Symbol and Book | 1969 | 2112 | [illegible]957 |
| RUSSIA (USSR)<br>Dmitri Mendeleev | 1934 | 536-39 | 588-91 |
| [illegible]*RUSSIA (USSR)<br>Nuclear Power Plant | 195[illegible] | 1794-96 | 1913-15 |
| RUSSIA (USSR)<br>Pierre Curie | 1956 | 1883 | 2003 |

| Country of Issue and Description | Year of Issue | Scott Catalogue Number | Minkus Catalogue Number |
|---|---|---|---|
| RUSSIA (USSR) Dmitri Mendeleev | 1957 | 1906 | 2029 |
| RUSSIA (USSR) Atom Bomb | 1958 | 2077 | 2212 |
| 61*RUSSIA (USSR) Nuclear-Powered Ice-breaker *Lenin* | 1958 | 2162 | 2298 |
| RUSSIA (USSR) Atom Diagram, Workers, Farmers | 1959 | 2236 | 2381 |
| RUSSIA (USSR) Atom Diagram, Rocket Launch | 1961 | 2504 | 2657 |
| RUSSIA (USSR) Atom Bomb | 1962 | 2614 | 2771 |
| 38.68*RUSSIA (USSR) Atoms for Peace | 1962 | 2625-26 | 2788-89 |
| RUSSIA (USSR) Atom Symbol and Power Line | 1963 | 2721 | 2886 |
| RUSSIA (USSR) Nuclear Test Ban Treaty | 1963 | 2811 | 2975 |
| RUSSIA (USSR) Nuclear Powered Ice-breaker *Lenin* | 1965 | 3106 | 3269 |
| RUSSIA (USSR) Nuclear Fission | 1967 | 3296 | 3448 |
| RUSSIA (USSR) Dmitri Mendeleev | 1969 | 3607-8 | 3761-62 |
| RUSSIA (USSR) Nuclear Submarine *Lenin Comsomol* | 1970 | 3756 | 3907 |
| RUSSIA (USSR) Ernest Rutherford | 1971 | 3888 | 4033 |
| RWANDA Atom Bomb | 1966 | 170-75 | 174-79 |

| Country of Issue and Description | Year of Issue | Scott Catalogue Number | Minkus Catalogue Number |
|---|---|---|---|
| 69*RWANDA Atom Diagram and Power Drill (Radioisotopes in Industry) | 1966 | 188,92 | 192, 96 |
| ST PIERRE & MIQUELON Pierre and Marie Curie | 1938 | B3 | 306 |
| SENEGAL Pierre and Marie Curie | 1938 | B3 | 206 |
| 61*SHARJAH & DEPENDENCIES Nuclear Merchant Ship NS *Savannah* (US) | 1965 | 86 | 126 |
| SOMALI COAST Pierre and Marie Curie | 1938 | B2 | 244 |
| SPAIN Wilhelm Roentgen | 1967 | 1460 | 1834 |
| SWEDEN Wilhelm Roentgen (with 1901 Nobel Prize Winners) | 1961 | 603-6 | 535-37 |
| 15*SWEDEN Becquerel, Pierre & Marie Curie (1903 Nobel Prize) | 1963 | 638 | 560 |
| SWEDEN Joseph John Thomson (with 1906 Nobel Prize winners) | 1966 | 710,12 | 599 |
| SWEDEN Ernest Rutherford (with 1908 Nobel Prize winners) | 1968 | 804,06 | 653 |
| 71*SWITZERLAND Nuclear Fission, 2nd Geneva Conference | 1958 | 369 | 819 |
| SWITZERLAND Atom Diagram and ITU Emblem | 1965 | 471 | 984 |

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| Country of Issue and Description | Year of Issue | Scott Catalogue Number | Minkus Catalogue Number |
|---|---|---|---|
| 73*SWITZERLAND European Organization for Nuclear Research (CERN) | 1966 | 475 | 994 |
| TOGO Pierre and Marie Curie | 1938 | B1 | 153 |
| TOGO Atom Diagram and Microscope | 1961 | 410 | 411 |
| 50*TOGO Nimbus Weather Satellite | 1964 | 502,5 | 529, 32 |
| TOGO Nuclear Merchant Ship NS *Savannah* (US) | 1968 | C92 | 733 |
| 50*TOGO Apollo Astronauts on Moon (Radioisotopes in Space) | 1969 | 674-77, C107-8 | 784-39 |
| TOGO Wilhelm R[illegible]en | 1969 | 692,C113 | 810-11 |
| TURKEY Marie Curie | 1935 | B67 | 1167 |
| 6,39*TURKEY Nuclear Research Center | 1963 | 1584-86 | 2347-49 |
| TURKEY Atom Diagram and University | 1966 | 1722 | 2533 |
| UNITED ARAB REPUBLIC Atom Diagram and Education Symbols | 1961 | 540 | 810 |
| UNITED ARAB REPUBLIC Atom Diagram and Rocket | 1962 | 567 | 840 |
| 67*UNITED NATIONS International Atomic Energy Agen[illegible] | 1958 | 59-60 | 64-65 |

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| Country of Issue and Description | Year of Issue | Scott Catalogue Number | Minkus Catalogue Number |
|---|---|---|---|
| 54•UNITED NATIONS Nuclear Explosion | 1964 | 133 | 145 |
| 70•UNITED NATIONS Suspension of Nuclear Testing | 1967 | 177-78 | 189-90 |
| UNITED NATIONS Nuclear Non-Proliferation Treaty, Nuclear Explosion | 1972 | 227(U.S.)<br>23 (Swiss) | 241<br>23 |
| UNITED STATES Atoms for Peace | 1955 | 1070 | CM382 |
| UNITED STATES Atom Diagram and Map of Oklahoma | 1957 | 1092 | CM404 |
| UNITED STATES Surface of Sun (Fusion Reaction) | 1958 | 1107 | CM416 |
| 60•UNITED STATES Nuclear Submarine USS *Nautilus* | 1959 | 1128 | CM437 |
| UNITED STATES Atomic Energy Act | 1962 | 1200 | CM509 |
| 23•UNITED STATES Albert Einstein | 1966 | 1285 | 623 |
| 51•UNITED STATES Apollo Astronaut (Radioisotopes in Space) | 1969 | C76 | A76 |
| VIETNAM, SOUTH Nuclear Reactor | 1964 | 231-34 | 269-72 |
| ZAMBIA Nimbus III Weather Satellite | 1970 | 61 | 165 |

# Album Pages for Additional Nuclear Stamps

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